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ESSOR

REACTOR AND HOT LABORATORIES

AN INTEGRATED FACILITY FOR IRRADIATION

AND POST IRRADIATION EXAMINATION OF

REACTOR COMPONENTS

for

HEAVY WATER POWER PLANTS PROGRAMS

Selected topics for

experimenters and

customers

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Commission of the
European Communities

Ispra, 13-2-1969
OR-3/358/69

ESSOR REACTOR PLANT

Information for the benefit of prospective users of :

- core positions and available in-pile sections ;
- caves and available cooling loops ;
- hot cell facilities.

Part 1 = Generalities
Part 2 = Technical Specifications

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PART 1

Generalities

Section A	=	General description of the ESSOR plant.
Section B	=	Proceedings of the meeting held at Ispra on the 3rd and 4th of september 1968 on the operation of ESSOR in the frame of the heavy-water power reactors development programs.
Section C	=	Irradiation in rigs and loops in the frame of explorative studies.
Section D	=	Subsidiary applications. Aids to nuclear plant owners and utilities.

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SECTION A

GENERAL DESCRIPTION OF THE ESSOR PLANT

The ESSOR plant is essentially a component testing reactor with two adjoining laboratory wings for hot components.

The reactor itself is designed for irradiation of fuel elements and channels of the heavy water reactor line in power reactor environment, with regards to neutron spectrum, cooling and fuel assemblies.

The functions of the two hot laboratories are : dismantling, inspection and metrology of fuel elements (ADECO), and similar treatment of structural components, channels, control rods, etc. (ATFI).

The plant facilities are completed by the presence on the grounds of the Ispra Research Center of a hot metallurgy laboratory (L.M.A.), and of transport and storage equipment for active waste.

1. The reactor

The ESSOR reactor core is arranged around an experimental zone filled with heavy water and providing space for 1 to 12 experimental channels with a maximum diameter of 170 mm.

The channels plunge vertically through the moderator. 1.50 m of their length is submitted to a flat flux of thermal neutrons $\geqslant 10^{14}$ n/cm^2/s.

The fuel elements introduced in the channels can generate from 1 to 2 MW according to design, enrichment and cooling conditions.

The maximum power of the experimental zone then amounts to about 20 MW.

The experimental zone is surrounded by a "driver zone" with high enrichment proven fuel elements, generating on the whole 25 MW.

The total power of the ESSOR core, with the experimental zone filled up reaches thus approximately 45 MW.

The operating cycle is three weeks full power operation and one week reactor shut-down for fuel handling.

The control system of the reactor core is located in the heavy water reflector, outside the driver zone to minimize the flux perturbation in the experimental zone. This arrangement involves on the other hand some limitations in the matter of reactivity control

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It is possible to connect several channels and fuel elements of the experimental zone in parallel to a single cooling loop. The following cooling mediums might be used : water, steam, gas or organic fluid.

Each loop is housed in a separate shielded cave, is provided with a control room in the reactor hall (connected to the main control room) and supplied with all auxiliary services (water, nitrogen, compressed air, vacuum, active and non active waste, power supply,etc...)

Five caves are available to the customers of the ESSOR plant.

Three of them are now occupied by the following experimental loops :

- EK 1 : CART loop with fog cooling,belonging to the CIRENE program of CISE (Italy)

- EK 2 : Organic loop for the study of the chemical properties of this coolant. Up to now the loop is not connected to any experimental channel. It might be of interest to the promoters of the ROVI program (Italy)

- EK 5 : Organic loop which should be connected to 4 to 5 experimental channels in parallel. The final adjustment work is in progress and the loop should be ready for the connection with channels and experimental fuel elements during summer 1969. Conceived within the ORGEL program, the loop may also be used in connection with fuel elements and channels of other heavy-water reactor lines, and in particular for the CANDU and SIEMENS concepts.

- 2 caves, EK 3 and EK 4 are available to other customers.

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2. Hot laboratory for fuel elements (ADECO)

After irradiation the fuel elements are discharged from the reactor core with one of the two shielded casks and deposited in the decay pool (when necessary after introduction in a storage container).

When the residual activity has decayed under 100.000 Ci γ (1 MeV) the fuel elements are conveyed under water to the main hot cell which is at the same time a dispatching station for the transport to the neutrography cell or to the metrology and conditioning cells.

The main hot cell is fully equipped with machine tools for any remote disassembling, cutting, milling, clad removing and sectionning work.

The neutrography cell for neutron radiography of fuel rods and clusters is not yet provided with the accelerator.

The other cells one designed for the following operations : metrology, leak test, gamma-scanning, puncture test, fouling test, etc...

The fuel rods are then sent to the Mean Activity Laboratory (L.M.A.) of the Ispra Center,for metallurgical examination of cladding (hardness, thermal and electrical conductivity, metallography, fission gas diffusion, etc...).

3. Hot laboratory for structural components (ATFI)

The cells are shielded for 7.000 to 10.000 Ci γ 1 MeV, but they have not the tightness requested by the handling of irradiated fissionable materials. They are thus devoted to structure components such as channels, control rods, structural elements etc...

The possibilities offered by these cells are outstanding with regard to the maximum length of the components hanled (up to 9 meters).

The first cell is equipped for the inner and outer inspection of the channels, for metrology and for cutting pressure and calandria tubes.

The second cell, of smaller size, serves for burst testing of tube sections and for machining of samples to be sent to the L.M.A.

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It is obviously possible to introduce in the hot laboratories irradiated components which are not coming directly from the ESSOR core.

For instance, a transport container may be unloaded into the decay pool with the 40 tons travelling crane : in this way it is planned to introduce in the ADECO Laboratory some fuel elements of the PWR reactor of Trino-Vercellese.

Several mobile containers with lead shielding and the necessary trucks and trailers, licenced for open road transport, are available at the Ispra Center. With this equipment we can take charge in any country of the Community of components of a wide range of activity and size delivered by customers and to be examined in the ESSOR plant.

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SECTION B

PROCEEDINGS OF THE MEETING HELD AT ISPRA ON THE 3rd AND 4th OF SEPTEMBER 1968

Scope of the meeting : Irradiation programs in ESSOR : survey of possibilities vs requirements and wishes or interests of reactor promoters.

Attended the meeting :

CEA	:	Mr.	BAILLY
CISE	:	Messrs.	MORANDI SCARONI
CNEN	:	Messrs.	AMBROSINI MANCINI
GAAA	:	Mr.	BOIRON
INTERATOM	:	Mr.	MARKFORT
MONTEDISON	:	Messrs.	BIONDI SCHIAVELLO
SIEMENS	:	Mr.	STEHLE
ESSOR	:	Messrs.	BONNAURE LECOQ
LMA	:	Mr.	KLERSY
D_2O Program	:	Mr.	CHARRAULT

The meeting began with a review of the main characteristics of the ESSOR complex and of the carrying out of experimental programs. A preliminary report, resuming the main items of information was distributed.

As requested by the participants, Mr. Bonnaure outlined the reactor operation schedule and the remaining possibilities for irradiation, not yet scheduled (Appendix 1).

Precisions were given on the necessary steps requested by the realisation of a new loop, from the first concept to the execution of the tests (Appendix 2).

As it was clear that, in the frame of the meeting no hypothesis should be made on the financing of new programs, nor on the maximum of the corresponding budgets, the participants expressed their wishes concerning the operation of the reactor and hot laboratories (Appendix 3).

On the basis of the possibilities of the reactor and of the requirements of the participants, four typical attempts of a future utilisation program for the whole experimental loops of the reactor have been outlined (Appendix 4).

APPENDIX 1

	1968	1969	1970	1971	1972	1973
Reactor	final tests operating license low power tests	rise to power 100% power tests final tests on channels start up	full power	operation		
Loops site		loading channels and modifications				
CART 1	out of pile tests low power tests	power tests wait	full power	irradiations		
MK 5 5	commissionning tests	modifications connect to channel fin. test	"			
" 6	"	"	"			
" 7	"	"	"			
" 8	"	"	"			
MK 5 ? 9	"	" If not	used by ORGEL	may be	connected to	a new loop
" 10	"	"	"	"	"	"
EK 2 2	built, waiting	tests connect to channels 3 final ? tests	"			
EK 3 3	" "	completing equipment * tests *	"			
Other loops if decided 4	discussions	design Manufacturing site erection	Tests **	Full power	irradiations	
" 11	"	"	"	"		
" 12	"	"	"	"		
Rabbit etc...	partly installed					

/ Temptative reactor operation schedule /

(*) these actions are possible but not scheduled at the moment

(**) connecting the loop to the channel should in this case imply a few months of reactor shutdown

APPENDIX 2

TYPICAL TIME SCHEDULE FOR THE INSTALLATION OF A NEW LOOP IN ESSOR

Approximative time evaluation	Step
6 months	1. - Discussion step (necessary to get a general agreement with the Commission) Scope and general description of loop and program Temptative design Temptative cost evaluation Temptative time schedule
3 months	2. - Preliminary design Same points as above but more detailed Start of the safety report study
18 months	3. - Realisation phase Detailed engineering design Submitting detailed safety report to Authorities Manufacturing components Assembling in the caves Associated-works in the ESSOR-Reactor plant (auxiliaries) Acceptance tests, including official inspection
3 to 5 months	4. - Upper and lower chamber works At the same time : - core loading - interlock modifications - final operation tests, including channel and fuel handling and remote control from the main control room

2 months : 5. - Start-up

Interlock and procedures operational control

Final safety agreement

Low power tests

High power tests

Full power operation

Total time = from 27 to 34 months, depending on management, interferences with running reactor programs, inherent complexity and safety.

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Tasks 1-2-3 may be performed during normal, full power, reactor operation.

Task 4 implies a reactor shutdown and partial unloading of the core.

Tasks 2-3-4 may somehow overlap upon each other.

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Step 1 leads to basic agreement, cost sharing and contract.

Step 2 provides necessary documents for a preliminary agreement of the ESSOR Safety Committee.

Steps 3 and 4, cover effective construction and commissioning tests.

Step 5 belongs to operational tests and final safety inspection for operation license.

APPENDIX 3

A. IRRADIATION

I. Present facilities

ESSOR customers are :

CISE : CART loop (CIRENE program). Fog cooled, light water. Channel 1.

EURATOM : MK 5 and EK 2 loops (ORGEL program). Organic coolant. Channels n. 5, 7, 8, 9 and 10 for MK 5, channel 2 for EK 2.

Status

CISE : CART loop ready. Will participate in ESSOR start-up to power.
Its irradiation program, in 1969, will be handicapped by the extended stop made necessary by loading ORGEL channels in the core and by the new start-up tests of ESSOR with organic loops.
Full power irradiation in 1969 is considered of first importance for the CIRENE fuel development program.
Irradiations are expected to extend on 1970 and 1971, possibly later.

ORGEL : MK 5 and EK 2 loops are complete, but they need fitting and adjustment work.
Loading of ORGEL channels in the reactor core is scheduled in summer 1969 and final tests, including start-up to power will take place during the second half of 1969.

MISCELLANEOUS : Existing facilities allow for samples irradiation both in organic loops, rabbit facilities and blind channels of low internal diameter.

Prospective

1970 will be a full power irradiation year for both programs.
In the course of 1970 or at the beginning of 1971, ORGEL irradiations will reach a branching point :

1) Either the construction of an ORGEL prototype will be decided and, then, the "Groupement Prototype" will take full use of MK 5 with 4 channels *(n. 5, 6, 7 and 8) and EK 2 with 1 channel (n. 2). In that case, all these sites will be occupied until 1972-1973.
2) Or the Commission will limit herself to complete the research and development tasks for ORGEL without any further attempts towards an industrial step.
In that case, the irradiations will go on until 1971 in channels 5, 6, 7, 8, 9, 10 of MK 5, and possibly in channel 2 of EK 2, though it could be conceivable to switch EK 2 on other jobs.

CISE : Foresees a prosecution of irradiations in CART over 1970 and 1971, even later.

SIEMENS : Could possibly irradiate UO_2/ThO_2 fuel samples, and Zr alloy cladding tubes in capsules cooled, by organic. EK 2 loop could be fairly easily adapted to this kind of experiment.
Irradiation conditions and device, still to be defined.

CNEN : Is interested in irradiation of high density fuel materials such as U-Si alloys.

MONTEDISON : Would be interested in completing and starting EK 3, in the frame of an irradiation program, in channel 3, of UC/SAP fuel in HB40 at about 200°C for the ROVI project. However, fitting and adjustment delays of EK 3, together with fuel development schedule let suppose that no such irradiation could take place in ESSOR before late 1970.

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* See annex 5

II. Operations involving new items

Prospective customers would be :

INTERATOM	:	Interested in irradiations of UO_2/Zr, high burn-up fuels in pressurized water loops.
CISE/CNEN	:	Hope to operate, besides CART, a fuel irradiation facility consisting of a fog loop connected to 3 channels, and a superheated steam loop, connected to 1 channel.
GAAA	:	No proposal, no comment
CEA/SIEMENS	:	No proposal, but (should a water loop be built and operated by EURATOM) would presumably perform some irradiations in this facility.

B. HOT LABORATORIES

1. Present or planned facilities

A detailed description of the ESSOR hot facilities and LMA (Medium Activity Laboratory of the Metallurgy Division) can be found in papers 5 and 6 of the document distributed during the meeting. The persons present had the opportunity to visit these equipments during the 2nd day of the meeting.
The possibilities offered to the customers are briefly reminded below.

1.1 A.D.E.C.O. (Fuel examination hot cells of ESSOR)

Washing wells (in operation)
Bundle dismantling machine (in operation)
Cutting machine (in operation)
Periscope (in operation)
Tightness-test (planned for end 1969)
Metrology bed for bundles and rods (planned for end of 1969)
Neutrography cell (planned for end of 1970)
Gamma scanning bed (planned for end of 1969)

1.2 A.T.P.I. (Pressure tubes examination hot cells of ESSOR)

Bed for internal and external TV examination (in operation)
Internal diameter measurement apparatus (planned for 1970)
Bowing measurement apparatus (planned for 1970)
Transversal cutting machine (in operation)
Cold helium leak-test (in operation)
Cold burst-test (in operation)
Hot burst-test (planned for end of 1969)
Milling machine for preparation of samples (planned for 1970)
Metrology bed for short pieces of pressure tubes (planned for end of 1969).

1.3. L.M.A. (Medium Activity Laboratory of Metallurgy Division) in operation as a whole

Main cell :

Puncture-test for fuel rods
Milling machine for scanning
Milling machines for ceramic fuels
Gamma-scanning
Stereoscopic-Periscope

Specialized lead-cells :
Metrology of fuel and sheath specimens
Density of fuel and sheath specimens
Dilatometer
Measurement of thermal and electric conductivity on cylindrical fuel specimens
Resin-coating and polishing of fissile and non fissile specimens
Microscope
Macro and micro hardness
Tensile tests (up to 600 °C)
Notch tests (5 kg x m from - 150°C till 600 °C)
Heat treatment furnaces till 2000°C
Fission gas release from fuel specimens and gas analysis

2. Prospective customers wishes

An interest has been manifested in the following items :

CISE/CNEN/ENEL (CIRENE program)

ADECO
- Bundles and rods dismantling
- Tightness test
- Metrology of bundles and rods
- γ scanning of rods
- Neutrography of bundles and rods

LMA

- Metallography on fuel and sheath specimens
- Tensile tests on sheath specimens
- Measurement of hydrogen pick-up on sheath specimens

ATFI

(Only for the second pressure tube ; end of 1969)

- Internal inspection
- Internal and external diameters
- Bowing
- Defect deppness measurements (due to fretting of grids on the channel).

CEA

The position of the C.E.A. concerning the utilization of ADECO and ATFI depends on a possible execution of an irradiation program in ESSOR.
The representatives from CEA do not exclude to use ATFI.

APPENDIX 4

Possible Combinations
for new loops in the ESSOR caves

1. 1 cave for 1 loop multipurpose — boiling water / pressurized water
   1 cave for EK 3 : ready for use
   1 cave for CART : CIRENE program
   2 caves for MK 5 and EK 2 : ORGEL program

2. 1 cave for 2 loops — 1 boiling water loop (and possible extension to superheated steam) / 1 pressurized water loop
   1 cave for EK 3 : ready for use
   1 cave for CART : CIRENE program (and possible extension to superheated steam)
   2 caves for MK 5 and EK 2 : ORGEL program

3. 1 cave for 1 pressurized water loop
   1 cave for 1 boiling water loop (and possible extension superheated steam)
   1 cave for CART : CIRENE program
   2 caves for MK 5 and EK 2 : ORGEL program

4. 1 cave for 1 pressurized water loop
   1 cave for 2 loops — 1 boiling water loop / 1 superheated steam loop
   1 cave for CART : CIRENE program
   2 caves for MK 5 and EK 2 : ORGEL program

As regards the potential use of new loops, prospective customers would be :

boiling water loop	: 3 channels for CISE/CNEN/ENEL (CIRENE program)
superheated steam loop	: 1 channel for CISE/CNEN/ENEL (CIRENE program)
pressurized water loop	: 1 channel for INTERATOM and/or SIEMENS
	1 or 2 channels for CEA.

APPENDIX 5

We received from GAAA on september 30th the following specification : should the ORGEL prototype choice turn on a natural uranium fuel, GAAA would like to have the MK 5 multiple loop equipped with a number of channels higher than 4.

APPENDIX 6

We reached on January 1969 an agreement with ENEL-FIAT for dismantling and inspection of 2 fuel bundles of the TRINO-VERCELLESE PWR power plant. This work will begin during summer 1969.

SECTION C

IRRADIATION IN RIGS AND LOOPS IN THE FRAME OF EXPLORATIVE STUDIES

1. Introduction

As we have seen in the section A, ESSOR is in the first place an irradiation facility for fuel elements and channels of heavy water moderated reactors, and secondly a testing facility for complete loops.

Unfortunately, the realization of these loops, channels and fuel elements requires a certain amount of time, whilst the manufacturer is usually interested in preliminary tests , or prefers to test subassemblies already at the project and development stage, by means of irradiation rigs, or in existing loops originally designed with a different purpose.

2. Possibilities of water reactor components testing in MK 5 loop

According to similar experiments, and in particular to the canadian reactor WR 1, it is possible to irradiate components of water cooled reactors (H_2O or D_2O) in one or several channels of the MK 5 loop. In this case the analogy existing between the thermal exchange of water and organic fluid allows this kind of test. Furthermore the MK 5 loop makes it possible to study the hydridation and embrittlement process of zirconium and its alloys, on account of their similarity of behaviour in presence of water or organic fluid.

See for example the following irradiations:

- cluster, or assembly of 1 to 3 fuel rods (triplet) for the heavy water/heavy water or heavy water/light water reactor lines, as: UO_2 - Zr Nb 2,5, UO_2 - ZY 4, UO_2 - OZEHNITE, UO_2 - Zr - Cu - Fe, U_3Si - ZYx.

- channels, calandria and pressure tubes with solid or gas insulation, made of stainless steel, zircaloy, SAP or new alloys.
- samples of cladding or structural material, diffusion barriers, hydrogen traps, etc.

Irradiation conditions in the MK 5 loop are very close to actual conditions in a water reactor with regard to power density, thermal exchange, hydrogen pick-up, etc. But the operating pressure in the experimental section will remain considerably lower than in a water reactor, so that cladding and channels cannot be submitted to pressures exceeding 20 kg/cm^2, although this limitation is not a serious handicap.

3. <u>Utilization of irradiation rigs</u>

Fall within this term devices such as ovens, irradiation cans, small indipendent loops, rabbit holes, etc., which can be introduced in the reactor core through a "glove-finger" tube plunging in the moderator or in the organic channels, holding small samples for irradiation (from samples of non fissionable material to complete fuel element rods).
To this purpose the ESSOR plant management has foreseen the adaptation of existing devices, designed and manufactured for other reactors like:

- CHOUCA: irradiation rig, usually for non fissionable material, in isothermal conditions up to 1000°C - Available in different sizes for sample diameters of 24 to 54 mm.
- CYRANO: irradiation rig for fissionable material; temperature of the fuel surface up to 1000°C, linear power 1700 W/cm max. Possibility of calorimetric measurements - Available in two sizes for sample diameters of 26 to 46 mm.
- HF5: irradiation ovens for chemical and physical studies at very high temperature (up to 2000°C). Max. sample diameter 24 mm.

Some measurements are made possible in these irradiation rigs, as: creep, swelling ,thermal conductivity, resistivity, pressure, etc.
All these rigs are reliable and already manufactured under standard conditions, which makes it possible to obtain them at short delay, also with active lenghts of 1,50 m ensuring a full utilization of the ESSOR flux.

At present the ESSOR reactor cannot admit many CHOUCA or HF5 devices, owing to the small reactivity reserve of the fuel charge, but the difficulty can easily be overcome, changing the specifications of the driver zone fuel elements, or accepting a less favourable economy of the driver zone cycle.

With regard to the CYRANO device the situation is better because the fissionable material of the rig compensates the absorption of the structural components,which has been reduced by an accurate choice of the material.

A double rabbit hole is also available in the ESSOR reactor core, with a diameter of 18 mm for samples of 14 x 40 mm, for short irradiation and activation analysis.

Irradiation of samples in the inner shell of modified driver zone elements is being considered. This could lead to studies on hard flux material behaviour in small sized samples at low temperature.

SECTION D

SUBSIDIARY APPLICATIONS

AIDS TO NUCLEAR PLANT OWNERS AND UTILITIES

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SECTION D

SUBSIDIARY APPLICATIONS
AIDS TO NUCLEAR PLANT OWNERS
AND UTILITIES

1. Introduction

Conceived for a specific task, namely the irradiation of core components in real size, as we have seen in the preceding sections, ESSOR offers the possibility to perform also other experiments. In the following lines an attempt is made to shape some of these possibilities.

On the other hand, the ESSOR reactor plant with its handling stations, decay pools, hot laboratories, decontamination hall, is the most suitable environment for the development of in-core inspection and intervention equipment, for testing underwater handling, and in general for the training of intervention teams available to the nuclear plant operators of the Community.

2. Other possible experiments

The main experimental channels have a considerable inner diameter; it is thus conceivable to introduce into the reactor core, both directly in the moderator or in the "glove finger" tubes, prototypes of control devices such as ionisation chambers with diameters reaching 150 mm, control and safety rods, etc...

The possibility of introducing control devices as well from the upper as from the lower plate of the reactor tank, allows to test, besides gas absorption and solid rods, also liquid absorption rods which must be introduced from the core bottom; this is a facility that is not offered by many other reactors.

- ESSOR may be useful for practical studies of "spectral shift" on a limited isotopic range of heavy water. Two Sulzer reconcentration columns are available for the extraction of light water passed accidentally or purposedly in the moderator or driver zone heavy water.

- In the driver zone heavy water loop, separated from the moderator, it is possible to experiment the chemical reactivity control by injection or extraction of soluble poison without excessive consequences on the reactivity.

3. Training of reactor plant operator staff for other reactors and utilities

As an experimental facility ,available to all member countries of the Community, ESSOR can receive apprentices of any mother language or nationality, such as : reactor operators, loop operators, hot laboratory technicians and health physics technicians.

Joint to the Ispra school for nuclear plant operator staff, a practice in the ESSOR plant might be adapted to the requirements of nuclear plant manufacturers and nuclear plant managers , as well as to the requirements of nuclear power stations, planned or already in construction in the Community.

4. Utilization of ESSOR staff and technicians for intervention and repairs in nuclear reactors or nuclear power stations

The operation of the reactor plant has made it necessary to collect the following technical facilities and corresponding know-how :

- inspection of reactor core :

  micro TV camera
  endoscope, boroscope
  macrophotography, remote inspection

- measurement of surface irregularities and deposit :

  optical
  mechanical

- special intervention tools :

  tightening tools
  screwing and unscrewing, cutting and disconnecting tools
  saws and cutting tools with remote control
  welding machine with remote control

- intervention and protection suits and equipment :

  masks
  protection suits for decontamination and fire-fighting
  breathing set in open or closed circuit.

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The research center is provided with additional decontamination and health physics equipment, that is :

- two intervention trucks meeting the prescriptions for transport by rail :

    - one equipped with health physics intervention set, decontamination showers, surface decontamination set, heavy-duty vacuum cleaners, dismantling tools,

    - one with a 12, 5 KVA generator and power supply system, 100 m^3/h compressor, pressure 7 atm, compressor for 225 ata, repair tools

- two lorries for hot components transport, with transport containers of different sizes, waste disposal tanks, etc...

This activity might be reinforced. The intervention team and the equipment could be available to nuclear plant owners in case of serious failure, asking for inspection and dismantling equipment to be employed in active or decontamination areas, underwater dismantling and machining, decontamination, etc...

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PART 2

Technical Specifications

Section 1	=	Reactor physics and irradiation
Section 2	=	General lay-out and equipment
Section 3	=	Experimental loop caves and control rooms
Section 4	=	Handling of reactor components
Section 5	=	Hot laboratories
Section 6	=	Medium activity laboratory (LMA)
Section 7	=	Data logging and processing (TIS)
Section 8	=	Safety procedures
Section 9	=	An irradiation device: MK 5

SECTION 1

REACTOR PHYSICS AND IRRADIATION

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SECTION 1

REACTOR PHYSICS AND IRRADIATION

1. GEOMETRY AND OPERATING CONDITIONS

1.1. Geometry

The horizontal section through the reactor core is shown in fig. 1. The stainless steel reactor tank (inner diameter 2.380 mm) filled with heavy water, contains :

- 8 peripheral channels disposed along a circle, diameter 1.750 mm, equipped with level meters for the heavy water (17 and 19), neutron detectors for the start-up of the reactor (23 and 24) and for the reactimeter (18 and 20), a gamma flux detector (21 ,gamma calorimeter)

- on a second circle, diameter 1480 mm, 16 control rods, namely :

  - 4 safety rods
  - 8 + 2 compensation and shim rods
  - 2 fine control rods

- along a circle, diameter 1180 mm, called the "driver zone", 16 ESSOR fuel elements, BR-2 type, cooled by heavy water in re-entrant channels.

The normal charge of U_{235} of these 16 elements is about 6300 gr.

The zone inside of this circle of fuel elements is reserved to the experimental channels. The axial shielding blocks now installed allow the passage of 12 channels in a rectangular grid of 256 mm pitch (see fig. 1). The diameters of the passage holes in the upper and lower shielding block are 170 mm and 134 mm respectively (see fig. 2). As the moderator inlet tubes must surround the channels in order to provide for their cooling, a free diameter of 150 mm (with a reduction to 114 mm in the lower shielding) is available for the experimental channels.

Between the channels there are 13 small tubes which are used to measure the distribution of the neutron flux in the irradiation zone by means of small mobile ionisation chambers.

The driver fuel elements have an active length of 1540 mm. The height of the heavy water of the moderator is 2370 mm. Above the heavy water there is an atmosphere of helium of 170 mm thickness.

1.3. Operating conditions

In the first core only the position 1 contains a channel, the other holes in the shieldings are closed by plugs. It is foreseen to install Orgel channels in a second core in the positions 5, 6, 7, 8, 12. The positions 2, 3, 4, 9, 10, 11 are for the moment available.

The total power of the reactor is 25 thermal MW in the 16 elements of the driver zone.

In normal operating conditions, the mean temperature of the heavy water moderator is about 48 °C, the mean temperature of the cooling heavy water is about 52 °C.

2. IRRADIATION POSSIBILITIES

2.1. Thermal flux

The thermal neutron flux in the central plane of the irradiation zone is at nominal power of the reactor, that is at 25 MW, about 3×10^{14} n./cm^2 sec (in Westcott units) , if there are no channels installed in this irradiation zone. The thermal flux varies by about $\pm$ 15% depending on the location in the irradiation zone : for instance at the axis of the reactor there is a flux of 3.4×10^{14} whereas nearby the fuel elements there is only a flux of 2.6×10^{14}.

Theoretically therefore small samples of fuel which do not cause any flux depression or self absorption could reach in the heavy water a specific power of $1.3. \times 10^4$ W/g U_{235}, corresponding to about 100 W/g of natural uranium.

The installation of irradiation channels, the organic coolants and also fuel elements ,depress the thermal neutron flux and hence also the possible specific power. A typical element of natural uranium with 19 rods in a double channel consisting of a pressure tube and a calandra tube of about 10 cm inner diameter depresses the flux in the moderator by about a factor of 2. In the channel itself and in the element the flux is once more depressed by a factor of 2, so that for natural uranium elements a mean specific power of about 25 W/g of natural uranium is possible. In small irradiation samples in an organic cooled channel one can expect about 50 W/gr.

The possible specific power of enriched fuel elements increases a little bit less than the enrichment, as the flux depression in the moderator and the self absorption in the element increases with enrichment. For a 1.7% enriched fuel element for instance one obtains 45 W/g of uranium.

The interference of the fuel elements in the irradiation channels under each other and with irradiation channels filled with coolant with respect to the flux and reactivity of the reactor must be studied for each configuration. In general the changes of the flux will not be too big (of the order of ± 20% with or without neighbouring elements).

Radial flux distribution

Fig. 3 shows as an example the experimental results of the relative distributions of the thermal neutron flux in the reactor mid plane for a configuration containing 8 elements of the Orgel type.

Axial flux distribution

Fig. 4 shows the axial distribution of the thermal neutron flux along the driver fuel elements. At the end of the charge of uranium, a small flux peak towards the moderator can be observed. The axial asymmetry of the flux distribution is due to the control rods which remain in the upper part of the reactor. This flux depression reaches its maximum when the control rods are about half way withdrawn. However this influence is mainly limited to the circle of the driver elements. Along the fuel elements in the irradiation zone the axial deformation of the flux is rather small.

For example, fig. 5 shows an axial asymmetry which is of the order of $\pm$ 20 % (furthermore one sees in this figure a rather important flux peak in the center of the reactor which is due to the grid of a fuel element of the Orgel type composed of two sections).

If the elements to be placed in the irradiation zone are shorter than those in the driver zone, the axial distribution in the active part become flatter. However at the ends one has a rather big flux peak which can be partially eliminated by a follower.

If no elements are loaded in the irradiation zone, the thermal neutron flux is about sinusoidal with an extrapolated core height of 200 cm.

Azimuthal flux distribution

A typical example of the variation of the thermal flux around a fuel element is given in fig. 7 ; in this particular case, the charge of the irradiation zone was not symmetric around the position 5, nevertheless the azimuthal variation remained within $\pm$ 7 %.

2.2. Fast neutrons

The flux of the fast neutrons for energies $>$ 1 MeV is of the order of 10^{13} n/cm^2/sec in the driver zone. If there are no elements loaded in the irradiation zone, the fast flux is about 1000 times smaller on the axis of the reactor. The axial distribution is given in fig. 8 for fast neutrons of several velocity groups.

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2.3. Gamma doses

In the driver zone, at the reactor midplane, the gamma dose is of the order of 10^9 r/h (corresponding to about 3 W/g). This dose decreases by a factor of 10 on a distance of 40 cm in the heavy water. On the axis of the reactor and on the inner surface of the vessel a gamma dose of 10^8 r/h is expected.

3. REACTIVITY

There are 8 control rods foreseen for the compensation of the changements of reactivity of the core during operation. As the position of these rods on the circle outside of the driver zone has been chosen so as minimize the flux variations in the irradiation zone, their reactivity value is rather limited. Furthermore, this reactivity varies with the loading of the reactor. In a core with 16 driver fuel elements and with the irradiation zone full of heavy water, the 8 compensation and shim rods have a reactivity of about 16%. With 6 elements of the Orgel type,(which represent a total of 1800 gr. of U_{235}) the reactivity of the 8 rods is only 10%.

The 8 rods must first give a shut-down margin of 1% when the reactor is cold and unpoisoned; then they have to compensate the Xenon and Samarium poisoning as well as the cold-hot reactivity, which amount to about 5%. The reactivity effect of the burn-up of fuel elements is estimated to 3 %.

Hence, there remains only about 1% to compensate the reactivity change due to variations of the core charge (i. e. loading or unloading of fuel elements in the irradiation zone). As one sees, the available reactivity of the control rods is not quite sufficient to compensate the effects of different charges of the irradiation zone. Hence one will have to compensate the reactivity by other means. With the existing driver zone fuel elements of ESSOR, the reactor will in general have an excess reactivity when test fuel elements are loaded and this can be compensated by adding an absorber to the moderator ;e.g. 1% of light water in the heavy water moderator diminishes the reactivity by about 10%. If one should have to mount provisionally empty channels in the irradiation zone, it would be necessary to increase the charge of uranium of the driver zone, which necessitates to order elements with higher uranium contents (with delivery terms of about 18 months).

If more thant 2000 gr of U_{235} should be charged in the irradiation zone, the efficiency of the control rods would decrease under 9 % and would then no longer be sufficient to compensate the burn-up; in this case, it would be convenient to increase the number of the control rods.

Also the efficiency of the safety rods must be checked in the case of an important loading in the irradiation zone. The necessary efficiency of course depends on the reactivity which can be liberated in a maximum credible accident, It depends hence on the nature of the coolant of the fuel elements to be tested. For organic coolant, which is an absorber of neutrons, the efficiency of the safety rods must be rather high.

4. OPERATING CYCLES

Operating cycles of normally 3 weeks are foreseen. Every three weeks the reactor will be shut down and 4 of the 16 driver elements will be replaced by new fuel elements. This operation causes an increase of reactivity of the order of 2.5%. Superimposed to these saw tooth shape reactivity variations , the decrease due to the burn-up of the test elements is to be noted.

This operating cycle involving unloading of 1/4 of the elements has been chosen in order to limit the flux variations and the reactivity changes from cycle to cycle and on the other hand to have a rather long irradiation period. In equilibrium the reactor contains hence 4 groups of ESSOR fuel elements with different degrees of burn-up (10, 20, 30 and 40% of the initial uranium charge.

5. CALCULATION METHODS

Despite the rather complex geometry of the reactor, and the big influence of the configuration of the irradiation zone on the reactivity and the distribution of flux in the reactor, a critical mock-up of the core is not absolutely necessary.

A new calculation method based on the heterogeneous theory has been developed and experimentally verified on some typical configurations. On the basis of this method, the TRIHET code, which uses two group diffusion theory, and the HETROIS code, which is similar but uses 3 diffusion groups, allow the calculation of K_{eff} of the reactor with a precision of $\pm$ 2% and of the flux distribution with a precision of the order of $\pm$ 10% (see fig. 9).

In order to calculate the burn-up of the reactor, the code ORACLE has been developed, which will be checked and adjusted according to the first experimental results to be obtained soon.

The fine flux distribution and the heat generation inside the test elements can be calculated with a combination of the existing codes THERMOS and DXY.

Finally, the test elements are equipped with in-core instrumentation (thermocouples, self powered beta detectors and Co dosimeters) which provide a better knowledge of the irradiation conditions (temperatures, specific powers, integrated powers).

LITERATURE

W. HAGE and others : "Symposium on Heavy Water Power Reactors" I.A.E.A., Wien, sept. 1967

Fig. 1

SCHEMATIC HORIZONTAL SECTION THROUGH ESSOR REACTOR CORE

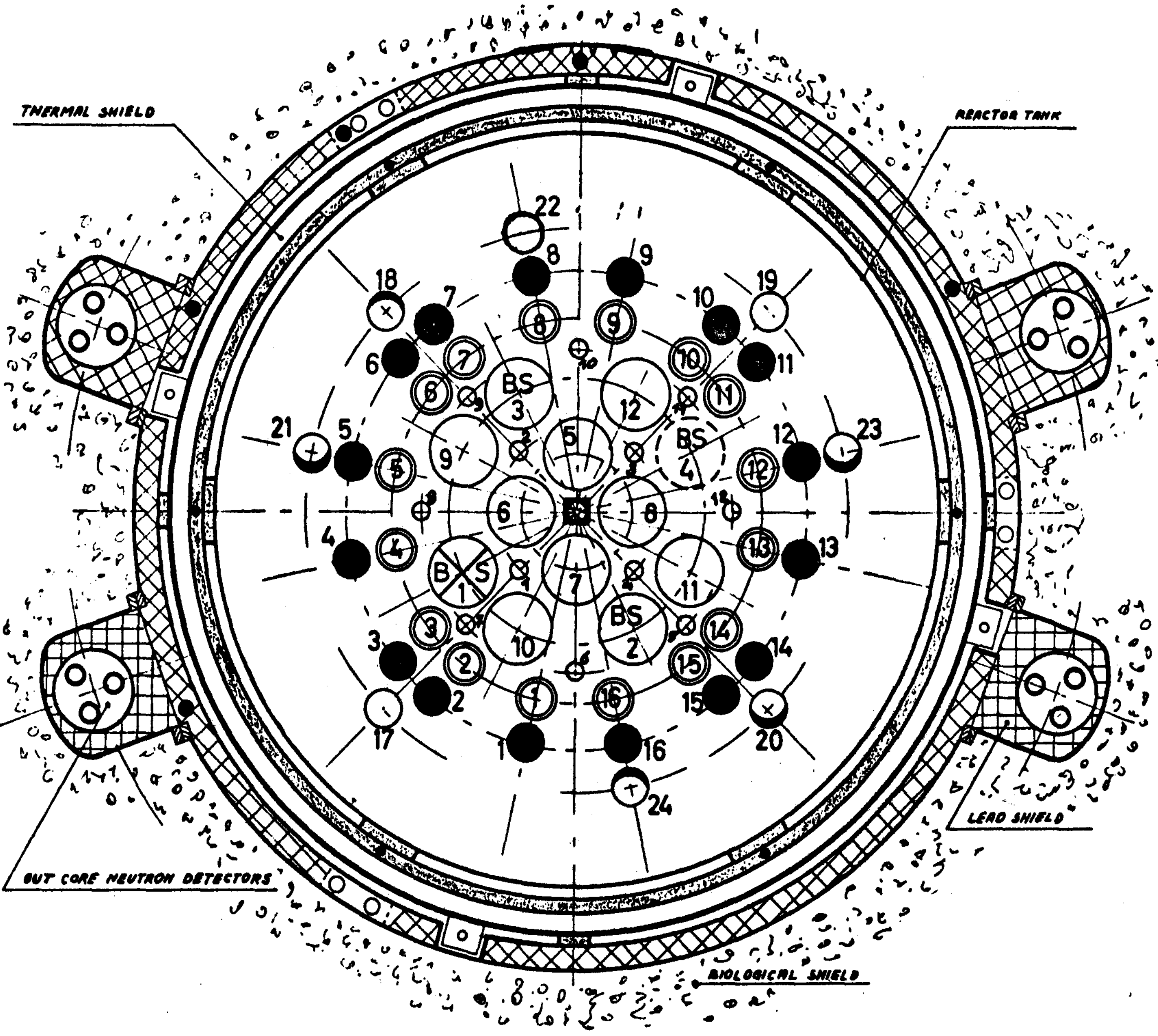
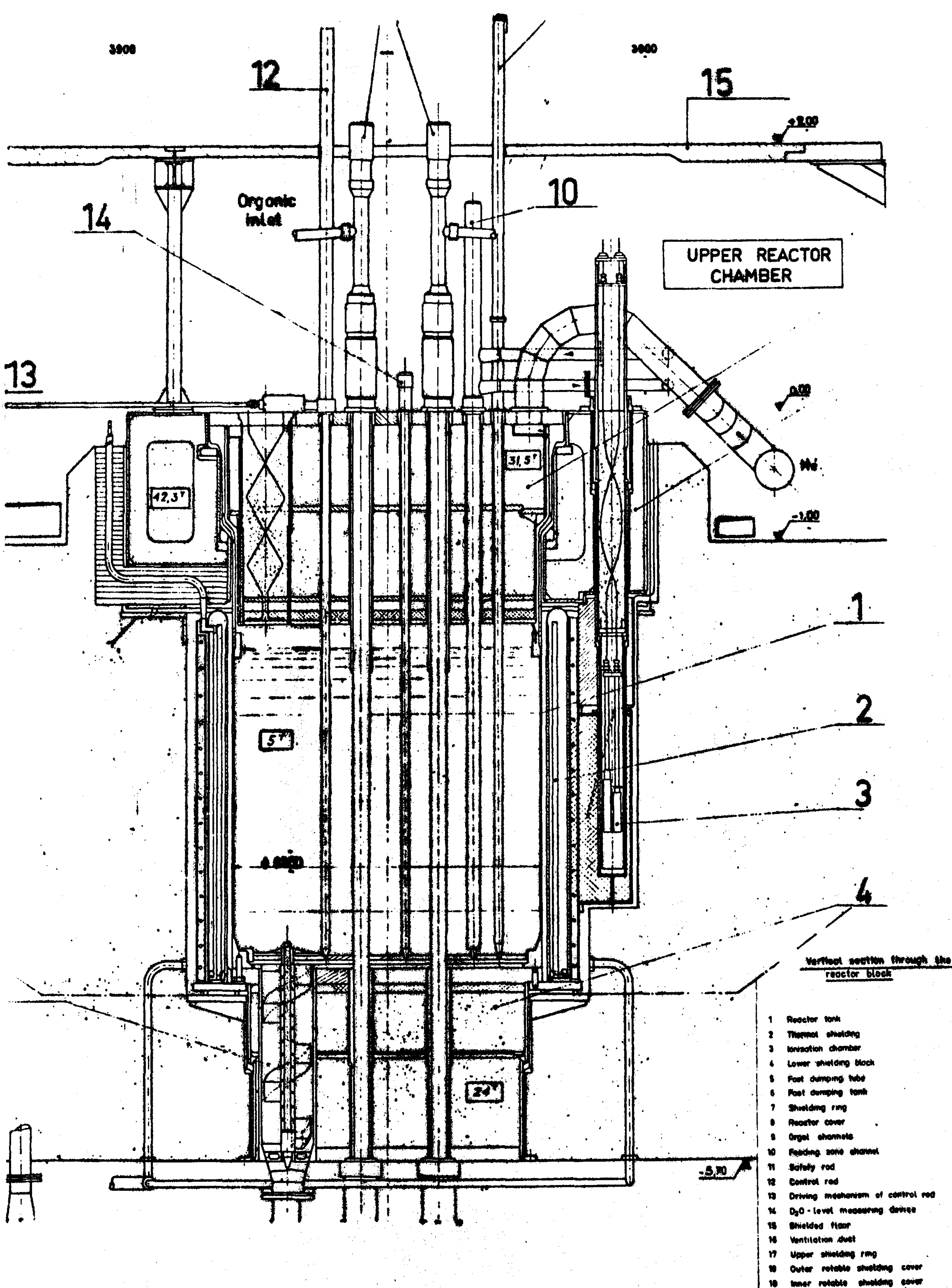


Fig. 2 VERTICAL SECTION THROUGH THE REACTOR BLOCK



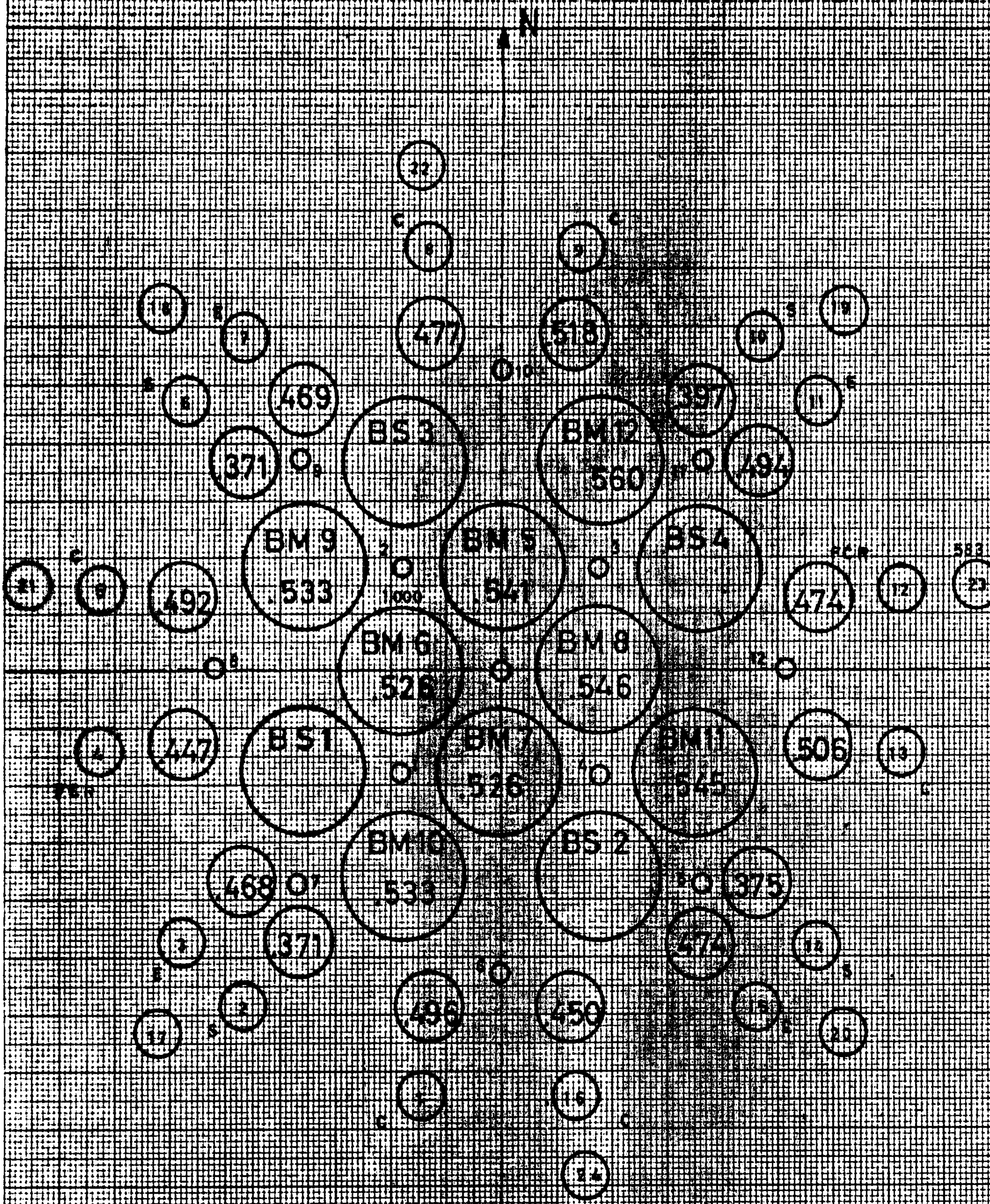


Fig. 3. Neutron density at core midplane Core 2-1a

FABRICATION SUISSE

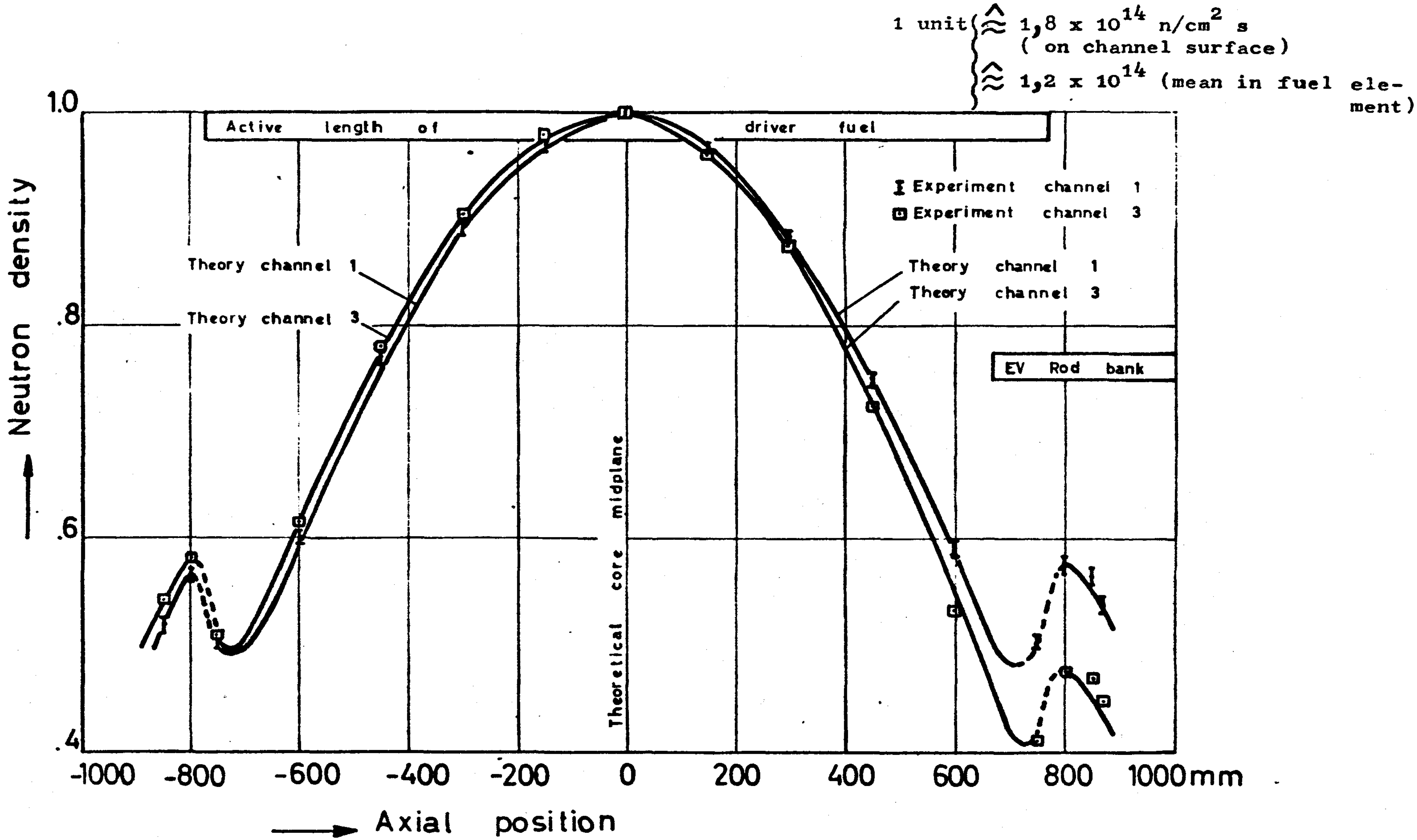


Fig 4 Relative axial neutron density distribution in driver zone element 1 and 3 in core configuration 1

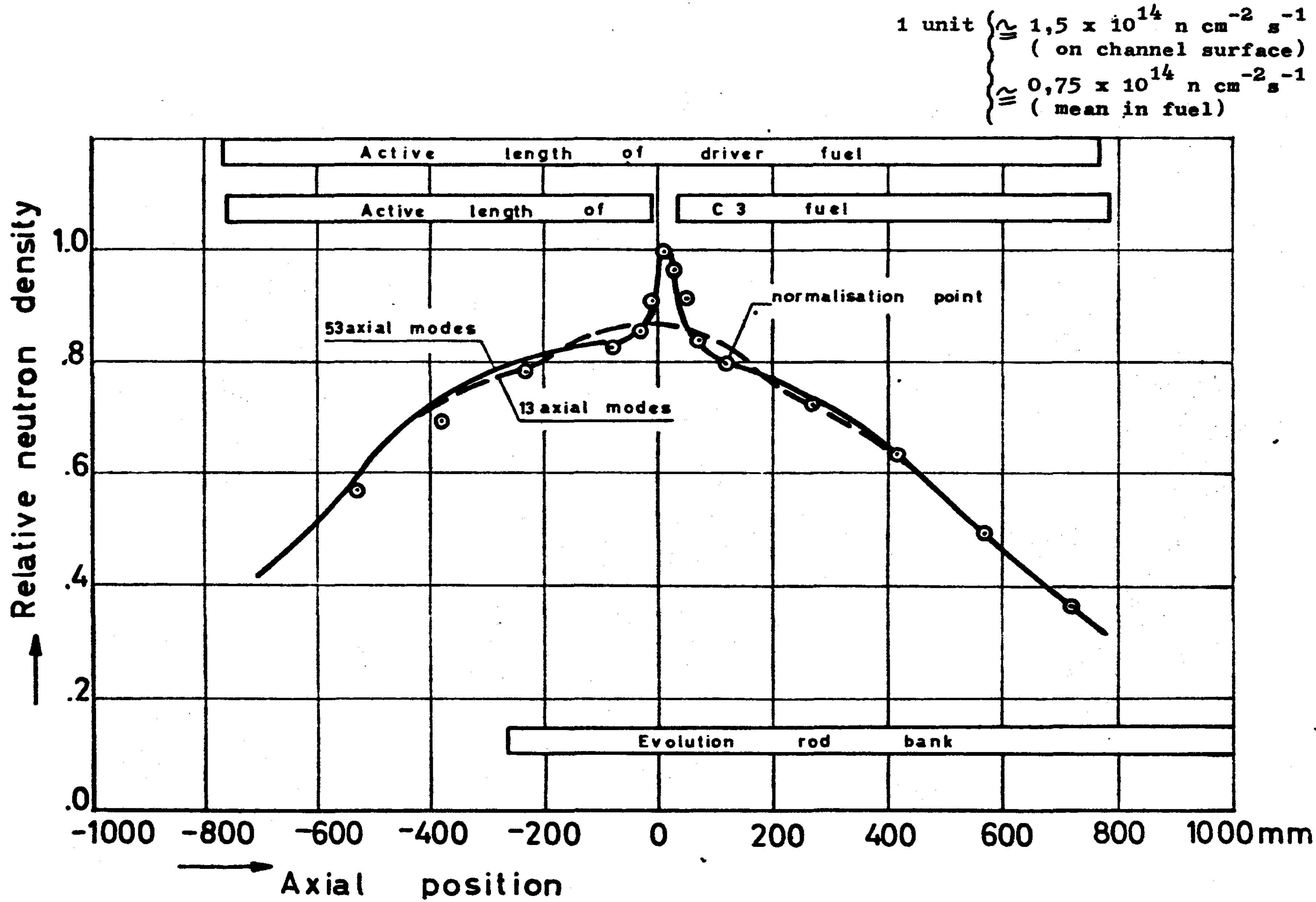


Fig 5 Relative axial neutron density distribution of C3 element in BM 10 in core configuration 6

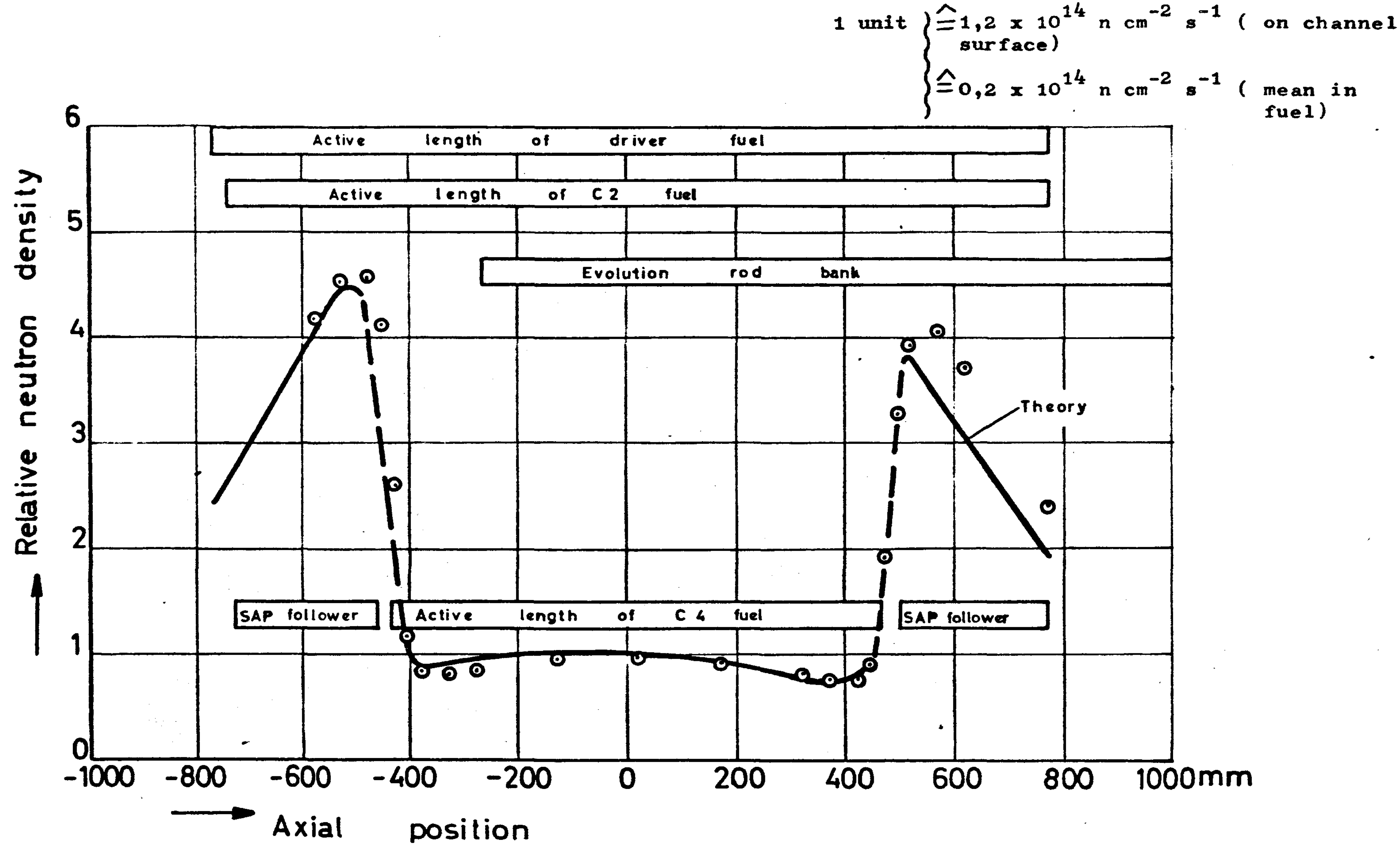


Fig 6. Relative axial neutron density distribution of C4 element in BS 3 in core configuration 6

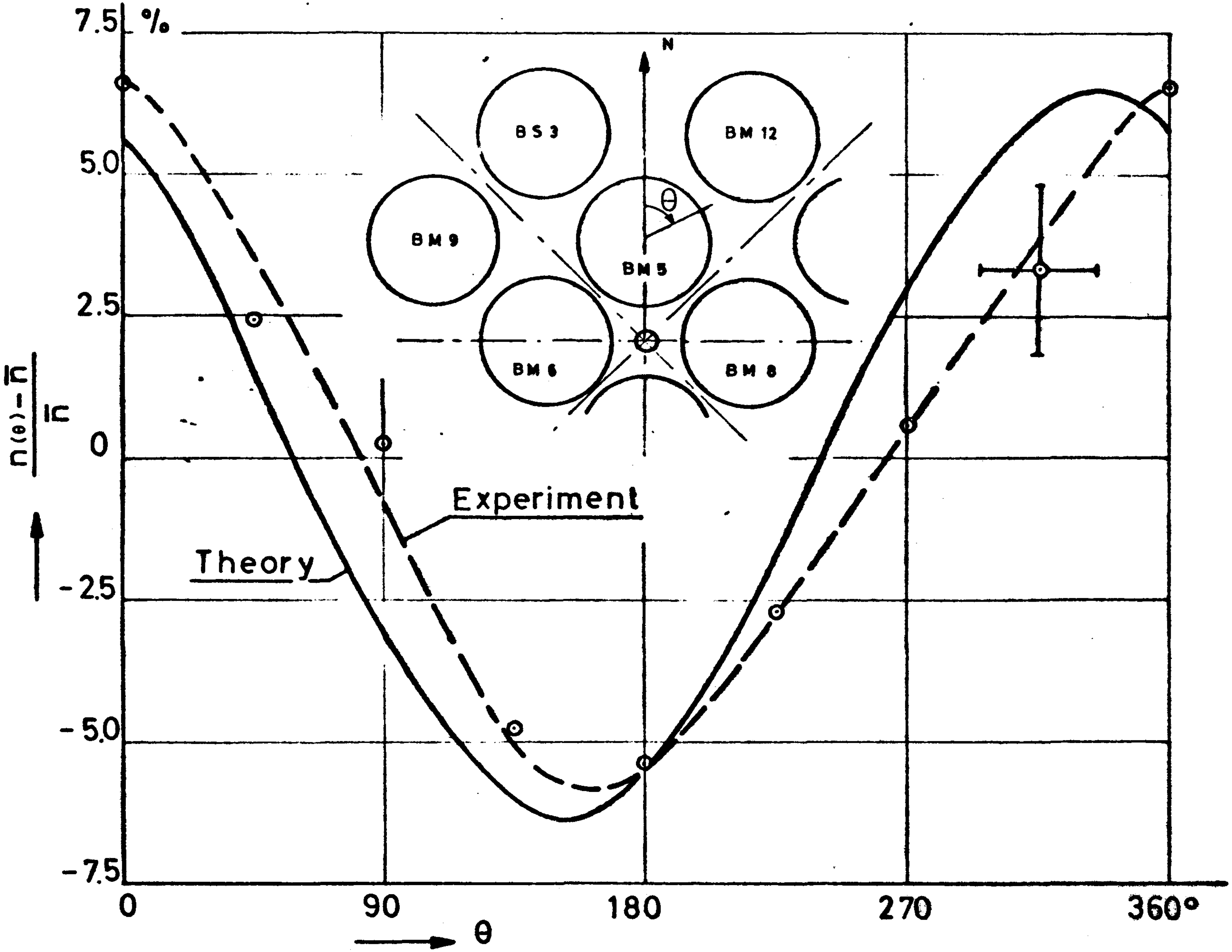
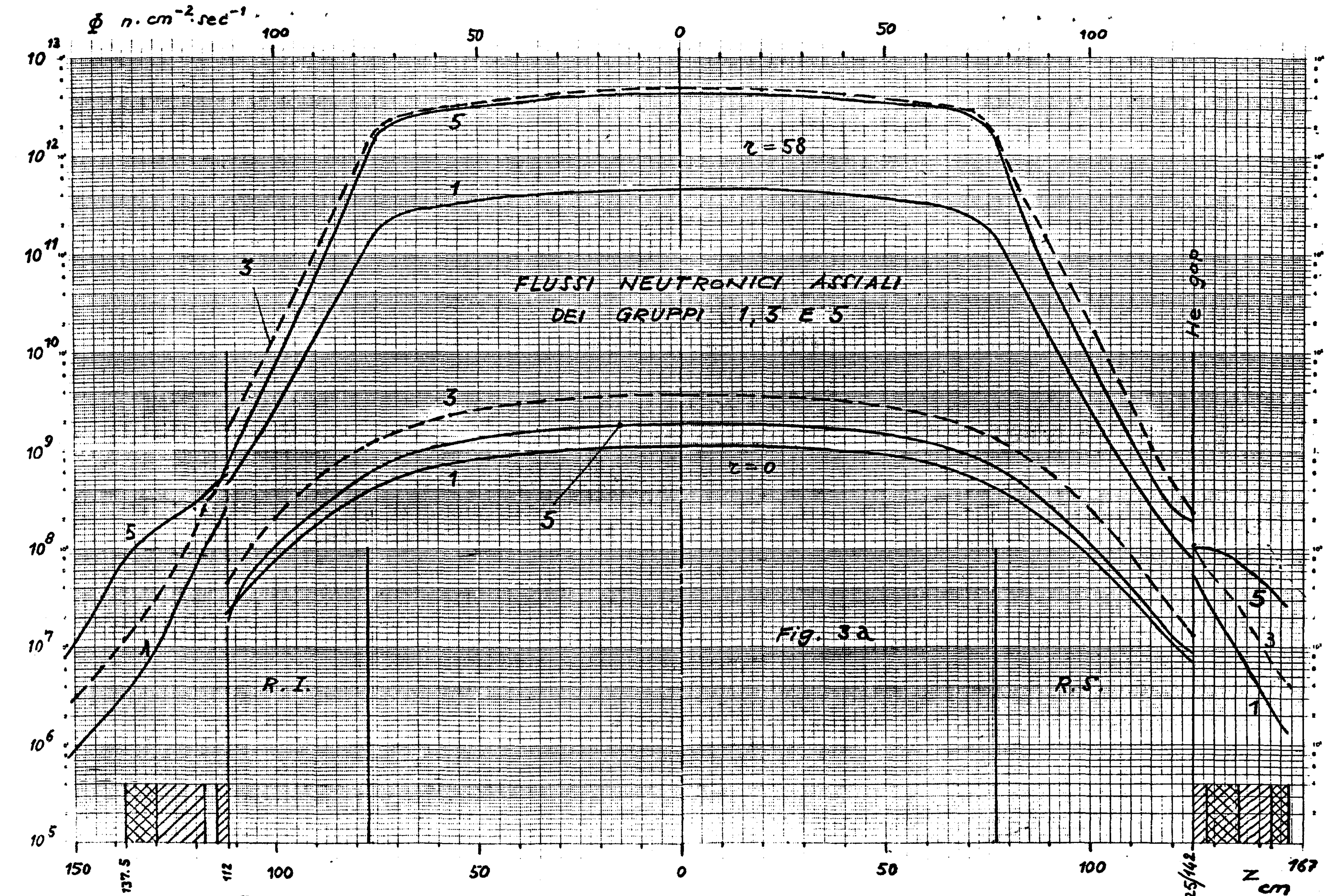


Fig 7. Angular deviation of the neutron density on C 2 element in BM5 and core configuration 6



Φ n.cm⁻².sec⁻¹
FLUSSI NEUTRONICI ASSIALI
DEI GRUPPI 1,3 E 5
r = 58
r = 0
He gap
R.I.
R.S.
Fig. 3a
z cm
150
137.5
112
100
50
0
50
100
125/142
167

/Fig. 8/

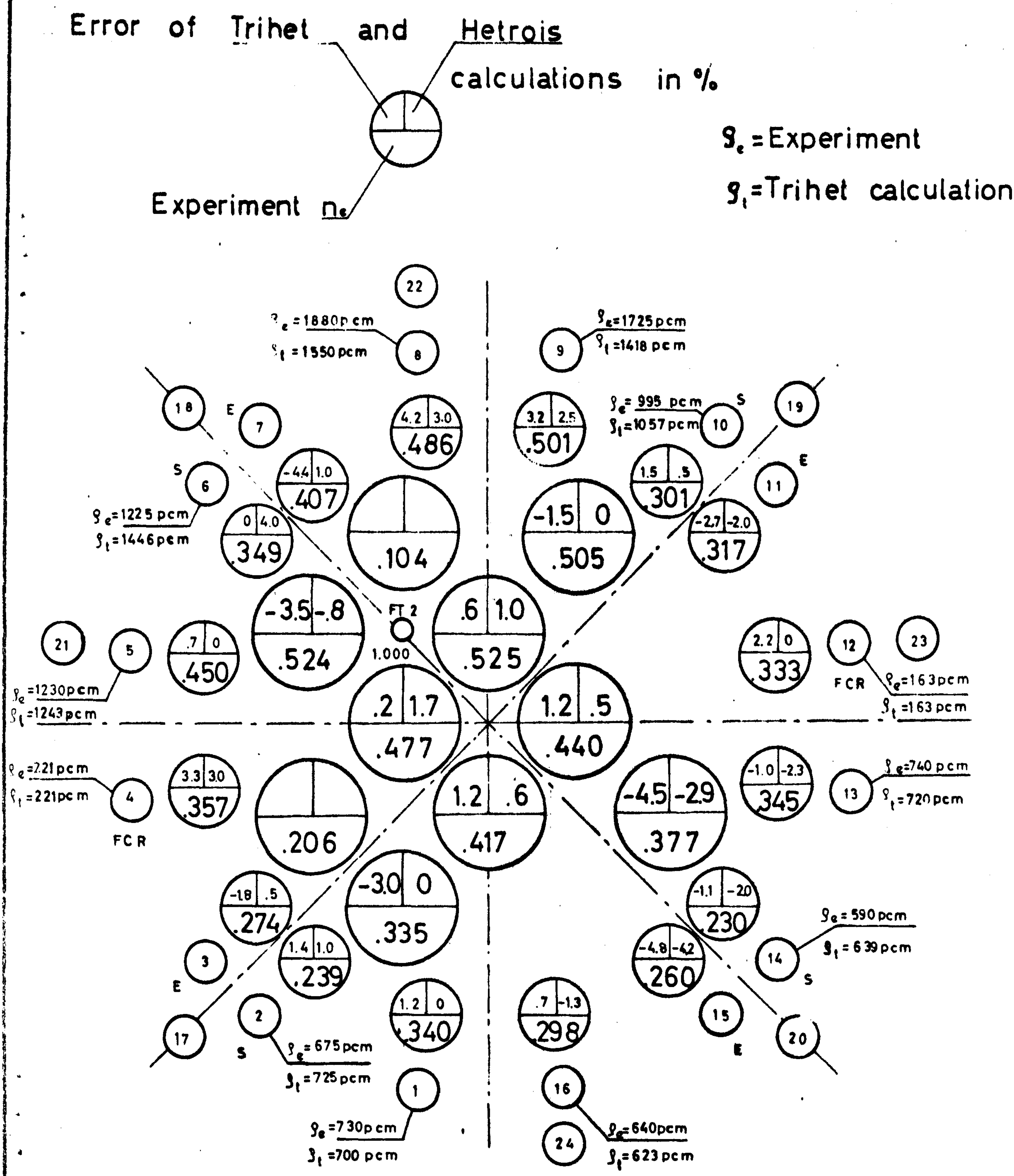


Fig 9. Relative neutron density distribution n_e at core midplane and error of theory $(n_e - n_t)/n_e$
Reactivity of control and safety rods by theory and experiment in core configuration 6

Section 2

GENERAL LAY-OUT AND EQUIPMENT

Index

Section 2

GENERAL LAY-OUT AND EQUIPMENT

1. Reactor containment

The metallic containment housing the reactor and its loops is a steel orthocylinder kept under pressure.

Diameter : 45 m.   Height : 45 m.

Wall thickness :

- up to the girder of the rotary crane	:	18 mm.
- above the girder	:	14 mm.
- on the dome	:	10 mm.

The lower part (12 m.) of the reactor containment is filled with normal or heavy concrete, providing several caves for the reactor, the loops, and the auxiliary systems.

The upper part (33 m.) is the so-called hall, the floor of which is 5 m above the external ground.

There is a 50 t. rotary crane, with a 5 cm fine adjustement of the radius for the axial operations and an auxiliary 5 t. hoist.

The entrance is allowed by 3 air locks : 2 for the personnel and 1 for the material (width 1,82 m, height 2 m), and by 1 truck-door (width 4,5 m, height 3,9 m) which can be opened only in absence of depression.

The reactor containment has been designed to whistand an overpressure of 250 g/cm^2 (test pressure 312 g/cm^2, overpressure for the maximum credible accident 125 g/cm^2) and an underpressure of 6 g/cm^2 (test underpressure 7,5 g/cm^2,normal working underpressure 4 g/cm^2). In order to limit the underpressure at - 4 g/cm^2, special low pressure valves open at - 5 g/cm^2 and close at - 4 g/cm^2; the underpressure is created by the ventilation system. The extraction, more powerful than the inlet, is provided with a buffer-volume allowing the ventilation in a closed circuit in case of contamination, or the outlet towards the stack (height 80 m) in normal operation.

In the reactor containment the ventilation renews the air 4 times/h , inlet flow : 65.000 m^3/h, and keeps both temperature and humidity in their normal range (20°C and 60% normally).

The power net of the reactor containment is "explosion proof" (VDE rules) in every room containing organic coolant and in any space with direct communication.

2. Cold workshop

The cold workshop has a surface of 13 x 25 = 325 m^2. It is provided with a 2 t. travelling crane. The main available tools are :

- 2 milling machines (a big one and a small one),
- 2 lathes (a big one and a small one),
- 1 saw
- 1 hand bending machine,
- 1 cutting machine,
- 1 roller,
- 1 electric welding machine,
- 1 argon arc welding machine,
- 1 autogeneous welding set,
- 2 grinding machines,
- 1 polishing machine,
- 1 hydraulic test pump.

3. Warehouse

The warehouse is located in a separate building about 50 m. from the reactor and has a surface of 500 m^2. It consists of 3 halls, 2 of which are provided with 3 t. travelling cranes. The halls have a ventilation and heating system but no air-conditioning.

The pallets are stored on shelves with a total capacity of 410 m^2 ; the shelves are provided with a set of drawers for small size items. There are 100 pallets with a maximum load of 1 t. each.

Cumbersome material or components weighing more than 1 t. and not so frequently employed, are stored in a 700 m^2 hangar without heating, or in a 1200 m^2 enclosure, according to protection requirements.

4. Power supply

In the ESSOR plant, there are 4 power supply systems and one lighting installation :

- 380 V, AC 3 ph., power (50 H_z)
- 220 V, AC 3 ph., control and instrumentation (50 H_z)
- 127 V, d.c., valves, control and signalisation circuits
- 24 V, d.c., measurements and control in case of 220 V failure

The 380 V, power network, consists of three independent bus bars, one of which is essential with right of priority. Each bus bar is fed by a Diesel generator set.

The power supply of the ESSOR plant is ensured by two H.V. cables (11.6 KV) connected to the substation of the research Center. Three transformers (plus one in stand-by) 11.600/380 V, 2 MVA, feed the three 380 V bus bars.

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5. Ventilation and auxiliary systems

5.1. Besides the ventilation of the reactor containment, there are other ventilation systems independent from each other :

- hot laboratories (ADECO and ATFI),
- conventional buildings,
- decay pool - H.B.R.,
- cooling, in a closed circuit, of rooms already ventilated by the general system :
  - upper reactor chamber,
  - lower reactor chamber,
  - organic loop caves,
  - data processing and control room,
  - synchronous motors room,
  - thermal shield.

5.2. Auxiliary systems

The ESSOR plant is provided with the following auxiliary systems :

- service water : 900 m^3/h,
- drinking water,
- superheated water; 60 m^3/h at 130°C,
- compressed air, 7 kg/cm^2 (1000 m^3/h may be supplied, twice the normal consumption)
- nitrogen
- steam
- vent lines and vacuum

  } see "section 3"
- non active used water and sewage
- active water

5.3. Fire-fighting system

The fire-fighting system is composed by a net of hydrants distributed everywhere in the reactor plant and by several spraying systems,general and local (3 organic loop caves, inner corridors of the reactor block, decay or storage pits, washing station, container packing station, entrance to the lower and upper reactor chambers).

A CO_2 fire-fighting system is available in the upper and lower chambers.

SECTION 3

EXPERIMENTAL LOOP CAVES AND ROOMS

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SECTION 3

EXPERIMENTAL LOOP CAVES AND ROOMS

1. Loop caves

1.1. Design parameters

Material : Reinforced concrete

Height : 14,5 m

Surface : 570 m^2

Maximum overpressure (burst-slug) : 1 kg/cm^2

(1)

L o o p	EK 2	EK 3	MK 5	EK 4
Height	14,5 m	14,5 m	14,5 m	14,5 m
Surface	57 m^2	57 m^2	71 m^2	57 m^2
Volume	826 m^3	826 m^3	1030 m^3	826 m^3
Static press.	1,2 kg/cm^2	1,2 kg/cm^2	1,2 kg/cm^2	1,2 kg/cm^2
Dim. concrete	2.00 x 0.70	2.00 x 0.70	2.50 x 2.00	2.00 x 1.70
Hatches	1.00 x 1.00	1.00 x 1.00	3.50 x 2.10	1.00 x 1.00

The overpressure is limited by the burst-slug.

The admissible overpressure for the concrete hatches is 1.2 kg/cm^2.

(1) EK 1 is not considered in this chapter. This cave is already occupied by the CART loop of the CIRENE program.

Service water

EK 2, EK 3, EK 4	38 m^3/h
MK 5	57,5 m^3/h

Light water

EK 2, EK 3, EK 4	17 m^3/h
MK 5	85 m^3/h

Compressed air : 3 and 6 kg/cm^2

Ventilation

EK 2	6015 m^3/h	fresh air	
EK 3	6015 m^3/h	fresh air	
EK 4	6015 m^3/h	fresh air	(maximum)
MK 5	7350 m^3/h	fresh air	

Maximum load for the steel bearings of the floors: 1000 kg/m^2.
Maximum load for the gratings : 500 kg/m^2.

1.2. Piping

Each loop cave contains about 50 pipe ducts and is provided with crossing points for pipes of 40 to 200 mm Ø.

EK 3 :	2 ducts	to the upper chamber
	2 ducts	to the lower chamber
	1 duct	to the melting station
	5 ducts	to the loop cave MK 5
	2 ducts	to the outer reactor corridor
	4 ducts	to the inner reactor corridor
	1 duct	to the reactor hall
	8 ducts	to the other loop caves (EK 1 - MK 5)
MK 5 :	1 duct	to the upper chamber
	1 duct	to the low chamber
	1 duct	to the melting station
	1 duct	to the lower chamber (Burst slug detection)
	1 duct	to the reactor hall
	1 duct	to the inner corridor
	1 duct	to the outer corridor
	3 ducts	to the outer corridor
	5 ducts	to the loop cave EK 3
	2 ducts	to the outer corridor
	2 ducts	to the loop cave EK 3
	8 ducts	to the loop caves EK 3 - EK 4
EK 2 :	1 duct	to the upper chamber
	1 duct	to the lower chamber
	1 duct	to the outer corridor
	1 duct	to the inner corridor
	1 duct	to the outer corridor
	2 ducts	to the outer corridor (service pipes)
	1 duct	to the vacuum line/to outer corridor
	8 ducts	to the loop cave EK 4
	8 ducts	to the outer corridor
	1 duct	to the EK 4
	1 duct	to the sampling

2. Auxiliary control rooms

2.1. Storage station

- Control panel:

  length : 2130 mm
  height : 2200 mm
  depth : 600 mm

containing :

- the auxiliary panels, switches, motor-protection switches, and measurement, control and display units. These latter are situated in the upper part of the panel.
- The flow-sheets, with push buttons for remote control, are arranged below.

2.2. Vacuum station

- Explosion-proof switch box

  height : 1690 mm
  width : 600 mm
  depth : 120 mm

- 2 consoles

  • Upper console :
  height : 1900 mm
  width : 4500 mm
  depth : 1000 mm

containing the auxiliary equipment for measurement and control, accessible through a door on the left side.

• Lower console:

height : 2100 mm
width : 4500 mm
depth : 1500 m

containing on the front side the flow sheet, and all controls, regulation and display units, accessible through a door on the left side.

2.3. Nitrogen station

- 21 Explosion-proof switch boxes

Total height : 1850 mm
width : 1800 mm
depth : 120 mm

containing the auxiliary equipment for control and measurement.

2.4. Experimental loops

The auxiliary control rooms of the experimental loops have the following dimensions :

EK 2, EK 3, EK 4	breadth = 4.50 m	length = 8.70 m	depth = 5.80 m
MK 5	breadth = 6.30 m	length = 10.00 m	depth = 5.80 m

Two rows of consoles are placed in front of the control desk. Dimensions of the first row:

EK 2, EK 3	length = 5150 mm	height = 1814 mm	depth = 500 mm
MK 5	length = 6150 mm	height = 1814 mm	depth = 500 mm

including a flow-sheet of the organic loop composed of removable and interchangeable units (25 x 25 mm), allowing quick changes of the flow-sheet by insertion of new indicator and control units.

The second row of consoles housing the electring and electronic equipment for remote control of valves, interlock sequences, and logic sequences. Most of the indicators are arranged on the flow-sheet.

The alarm lights are grouped above the flow-sheet.
The control switches of pumps, regulating valves and main measurements are situated on the control panel.
Two cable bundles go from each auxiliary control room to the loop caves: one for measurement and control (200 cables) and one for power supply (200 cables). The auxiliary control room of BK 4 will not be used for the moment.

Nitrogen

Nitrogen is supplied from a central station.
There are two different networks, one of 34 kg/cm^2 and the other of 3 kg/cm^2.
Main flow of these networks is 20 Nm^3/h.
In the central N_2-Station the industrial N_2 is purified; with a max. flox of 20 Nm^3/h, the contents of O_2 and H_2O should be $\leqslant$ 5 ppm.

Steam

The station provides the steam for the heating system of the organic loop.
It is composed of 3 Siller boilers with a capacity of 500 kg/h each, generating heat at a pressure of 5 or 20 atm.

Vacuum

The vacuum station consists of two different sections:

- Section for low activity gases,

  sucked by two liquid-ring pumps, in series with two gas ejectors.

  The first pump has a capacity of 100 Nm^3/h. Should additional capacity be required, the second pump (cap. 200 Nm^3/h) cuts in automatically.

  The gases go through activated-carbon adsorbers and a filter retaining all particles larger than 0.3 microns to the exhaust line.

- Section for high activity gases.

  This section is situated in a shielded room.

  The pump unit is identical to that of the low activity section.

  After leaving the adsorbers, the gases go through a series of ten decay columns filled with 2400 kg of activated carbon. In front of the absorption columns are 8 decay tanks, for storage and evacuation of radioactive gases at a rate exceeding that foreseen for the system. This buffer system has a capacity of 20 m^3.

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RATING

Installed Power in Auxiliary control rooms

VOLTAGE	EK 2		EK 3		MK 5		Storage station		Vacuum st.		N_2-station 8100 EQ 14		Steam station	
	KW	A	KW	A	KW	A	KW	A	KW	A	KW	A	KW	A
380 V 50 Hz B_1	26,4	58,2	63,4	102,8	28,8	63,6	----	----	----	----	----	----	----	----
380 V 50 Hz B_2	113,4	173	----	----	333,7	550	----	----	----	----	73	114	----	----
380 V 50 Hz B_3	18	37	16,5	34,4	28,1	55,6	----	----	54,6	116,8	----	----	63,4	129
220 V 50 Hz B_1	5	23	5	23	5	23	4	18,2	5	23	2	9,1	2	9,1
220 V 50 Hz B_2	5	23	5	23	5	23	4	18,2	----	----	----	----	----	----
127 V =	4	31,5	2,5	19,7	5	39,2	1	7,95	3	23,5	0,5	3,9	2	15,6
Installed Power ACEC-loop rooms (Pumps)														
380 V 50 Hz B_1	171	330	171	330	924	1680	----	----	----	----	----	----	----	----
380 V 50 Hz B_3	16,5	39	16,5	39	45	93	----	----	----	----	----	----	----	----

/ R A T I N G /

Max. Power (ACEC installation)

VOLTAGE	EK 2		EK 3		MK 5		Storage station		Vacuum station		N_2-station 8100 EQ 14		Steam station	
	KW	A	KW	A	KW	A	KW	A	KW	A	KW	A	KW	A
380 V 50 Hz B_1	46	100	57,5	125	46	100	---	---	---	---	---	---	---	---
380 V 50 Hz B_2	91	200	---	---	184	400	---	---	---	---	184	400	---	---
380 V 50 Hz B_3	29	63	29	63	29	63	---	---	46	100	---	---	91	200
220 V 50 Hz B_1	5,5	25	5,5	25	5,5	25	5,5	25	5,5	25	5,5	25	5,5	25
220 V 50 Hz B_2	5,5	25	5,5	25	5,5	25	5,5	25	---	---	---	---	---	---
127 V =	5,1	40	5,1	40	5,1	40	5,1	40	5,1	40	5,1	40	5,1	40
/ Max. Power (Loop rooms ACEC installation)/														
380 V 50 Hz B_1	405	730	405	730	1.270	2.300	---	---	---	---	---	---	---	---
380 V 50 Hz B_3	29,5	60	29,5	60	74	150	---	---	---	---	---	---	---	---

SECTION 4

HANDLING OF REACTOR COMPONENTS

Index

1. Introduction

2. Workshop for assembly and control of non irradiated reactor components (A.T.E.N.)

   2.1. Functions
   2.2. General equipment
   2.3. Assembly
   2.4. Instrumentation

3. Load-unload machines

   3.1. Driver-zone machine
   3.2. Experimental-zone machine

4. Handling stations (storage and conditioning in the reactor building)

   4.1. Assembly-disassembly station
   4.2. Intermediate storage station
   4.3. Decay pits
   4.4. Packing station
   4.5. Storage station for experimental channels
   4.6. Washing station
   4.7. Active material storage
   4.8. Non-active material storage
   4.9. A.T.F.I. air-lock
   4.10. Decay pool air-lock

5. Decay pools

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SECTION 4

HANDLING OF REACTOR COMPONENTS

1. Introduction

Each type of irradiation device follows a well-defined way between its entry into the ESSOR buildings and its storage in the decay pools after irradiation (fig. 1).

As a general rule, before its transfer into the reactor building, each in-pile equipment is commissioned and can be stored in the workshop for assembly and control of non-irradiated components (A.T.E.N.). This installation clearly represents the "main gate" of the reactor.

In the reactor building, the in-pile equipment will be manipulated with special handling machines, which will either transfer it into a preparation station or will directly load it into the reactor.

The irradiated material is unloaded from the reactor by means of the load-unload machines, which will direct it towards one of the handling stations located in the reactor building. Temporary storage and conditioning before transfer outside of the reactor building are performed in these stations.

Fissile irradiated material will be transferred in the decay pools and then eventually towards the fuel elements hot laboratory (A.D.E.C.O.); irradiated structural material and irradiation devices without fissile material will be transferred directly into the structural material hot laboratory (A.T.F.I.).

The different steps of this procedure are described in detail.

3. Workshop for assembly and control of non-irradiated reactor components (A.T.E.N.)

2.1. Functions

The A.T.E.N. has three main functions :

a) final assembly of in-pile devices (mechanical assembly and instrumentation),

b) final checking before irradiation,

c) eventual storage transfer into the reactor building.

2.2. General equipment

The A.T.E.N. is basically a large working hall connected with the reactor building by an air-tight transfer lock. In particular, the A.T.E.N. is equipped with three underground pits which allow to work at all irradiation device levels, and with two assembly benches that can be raised in a vertical position.

A 2 tons crane bridge handles pieces 9.05 m long.

The reactor building transfer air-lock may receive pieces 9.88 m long, with a maximum diameter of 250 mm and a maximum weight of 500 kg.

A completely closed fuel element storage room is installed in the A.T.E.N. hall.

2.3. Assembly

The equipment installed in the A.T.E.N. allows to perform the final assembly of all types of irradiation devices, including fuel elements in clean conditions. The device assembly is followed by a dimensional control and eventually a helium leak-test.

2.4. Instrumentation

The A.T.E.N. can install and control thermocouples, collectrons and, in general, all types of instrumentation, through leak-tight passages on irradiation devices. The instrumentation installation can be accompanied by partial leak-tests, radiographic control and final helium leak-test.

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3. Load-unload machines

Two shielded machines perform the operations of loading and unloading the core, transfer of irradiated devices between the storage and conditioning stations, and transfer of these devices outside the reactor bluilding. One of these machines (driver -zone machine, HZN) works mainly on the areas directly connected with the operation of the reactor (driver - zone fuel elements, control rods, etc...).

The other machine (HZE) performs the operations connected with the experimental area (fuel elements, channels, experimental devices, etc...).

3.1. Driver -zone machine (HZN)

The driver -zone machine has been designed to handle pieces immersed in heavy water.

Its main components are :

a) a lower carriage, common with the other machine, which travels on a East-West diameter of the reactor building ,

b) an upper carriage, which travels perpendicularly to the first.

The handling flask itself is installed on the upper carriage.

The lower carriage travels over an area which includes the reactor itself, the handling stations (storage and conditioning) and the airlocks leading towards the outside of the reactor building (A.T.E.N., decay-pool, A.T.F.I.). The main characteristics of the driver - zone machine are given on table 1.

The loading and unloading operations, and the irradiated fuel elements transfer are performed in a nitrogen atmosphere, under 1 and 4 ata respectively.

Pressurization of the machine is normally insured by the nitrogen distribution net. In case of nitrogen net failure, the machine is pressurized using its own nitrogen tanks.

In case of failure of the electrical hoisting device, the hauling operation can automatically proceed using a pneumatic motor. Should the hauling be interrupted without any possibility to complete the operation, the heavy water circuits will then lift up the heavy water level from the channel into the flask, in order to flood the hot fuel.

The failure of the nitrogen cooling system has also been foreseen. If such a failure should occur after closure of the valves of the machine foot, there will be an automatic flooding of the irradiated element with the heavy water contained in a tank installed on the flask itself.

3.2. Experimental-zone machine (MZE)

The experimental zone machine was initially designed for the handling of organic loop channels and fuel elements.

The machine has been modified to allow the handling of in-pile components cooled by other cooling fluids (water or gas). It is possible to switch from one cooling fluid to another after washing, rinsing and drying the machine.

The experimental-zone machine is built under the same principles as the feeding-zone machine : a common lower carriage and an upper carriage which holds the shielded flask and its hoisting device.

The main characteristics of the machine and its operational limits in the present conditions are given on table 2.

The normal loading and unloading operations are made in a nitrogen atmosphere under a 1 ata pressure; the nitrogen gas can be preheated before unloading of fuel elements in order to avoid thermal shock.

Should the electrical hoist fail, the hauling operation would automatically be carried on by the compressed air auxiliary motor. In the event of a failure of the compressed air motor, it is possible to lower the irradiated device by gravity into the core.

The transport of structural materials or non-irradiated fuel is made under a pressure of 1 ata. The transport of irradiated fuel elements is made with a 4 ata pressurization of the flask.

The pressurization of the flask is normally given by the general nitrogen distribution net. In case of failure of the nitrogen net, the flask can be pressurized using its own nitrogen tanks.

In case the cooling or pressurization could not be obtained, the irradiated fuel is automatically flooded, using a reservoir installed on the machine. The cooling liquid is then circulated through a pump and cooled by a special circuit.

If the irradiated fuel element should have suffered a cladding rupture, the nitrogen used for cooling would be passed on a charcoal filter.

4. Handling stations (storage and conditionning in the reactor building)

A block diagram of the general procedures for handling in-core experimental devices is given on figure 1. The location of the storage and conditioning stations installed in the reactor building is given on figure 2.

4.1. Assembly-disassembly station

The assembly-disassembly station is made of a shielded cave equipped with a pit where the following general operations can be manually performed :

- adjustment or change of the load-unload machine grabs
- maintenance or adjustment operations on the tools manipulated by the handling machines
- change of cooling shells inside the flask of the experimental zone machine, following the type of fuel element to be handled
- partial disassembly of the non-active upper part of experimental channels
- final assembly, check and control of non-irradiated experimental devices, before their introduction in pile
- installation of special heads on irradiated equipments to be transferred to the ATFI.

The present limit characteristics of the irradiated devices that could be handled in this station are given on table 3.

4.2. Intermediate-storage station

The intermediate storage station has been initially designed to receive irradiated organic cooled fuel elements and to let them decay in methylnaphtalene, until their residual power will allow their transfer to the decay-pool and to the hot laboratories in leak-tight containers.

The station is made of 16 vertical carbon-steel pits installed in a shielded cave.

The pits are filled with methylnaphtalene, under nitrogen cover. The methylnaphtalene can be preheated up to 200 °C to avoid thermal shock on the fuel elements during their loading. The residual power of the irradiated fuel is evacuated through the methylnaphtalene by a secondary water circuit.

The gaseous fission products eventually produced by the fuel are evacuated through the common vent circuit.

The present characteristics of the station are given on table 4, together with the limit characteristics of the existing pits.

4.3. Decay pits

The station is made of 5 vertical carbon steel pits installed in a shielded cave.

The station was initially designed to be used as a decay storage for organic cooled experimental channels containing an irradiated jammed fuel element.

This utilisation will be extended : some decay pits will be transformed in order to temporarily store fuel elements whose geometry is incompatible with the intermediate storage station (see parag. 4.2.).

In their final situation, which is foreseen to be operational in 1969, the decay pits will be used as follows :

- three carbon steel pits, filled with methylnaphtalene covered with nitrogen, cooled by a water jacket, will be mainly used for organic loops : storage of channels with jammed fuel element or storage of fuel elements incompatible with the intermediate storage station;

- two stainless steel pits which could be filled with methylnaphtalene or demineralized water, also cooled by a water jacket, will be used for non-organic loops : storage of channels with jammed fuel element or storage of fuel elements incompatible with the intermediate storage station.

The gaseous fission products eventually produced by the fuel are evacuated through the common vent system.

The characteristics of the station are given on table 5, together with the limit characteristics of the pits.

4.4. Packing station

The packing station has two main functions :

- cutting of the suspension rod of irradiated fuel elements in order to reduce the length to be transferred into the decay pools;
- lowering of irradiated fuel elements into their leak-tight container which provides a better cooling during the transfer operations outside of the reactor building and avoids direct contact of the fuel element with the demineralized water of the decay pools.

The station is made of a large leak-tight tank installed in a shielded cave. The support structure for the storage container and the container closing device are all installed in the tank.

The control of the various operations is remotely performed from a shielded control room, with the help of a television closed circuit.

The storage containers are designed following the type of fuel to be handled. They can be filled either with methylnaphtalene or with demineralized water.

The experimental-zone load-unload machine transports the storage containers from the packing station into the decay-pools, where they will be stored before unloading of the fuel in the hot laboratory (see parag. 5).

The characteristics of this station and of the storage containers are given on table 6.

4.5. Experimental channels storage station

A shielded cave equipped with 20 **sheaths** is used for the decay storage of irradiated experimental channels before their shipment to the hot laboratory ATFI.

The casings are interchangeable and are designed following the type of device they will receive.

The station can accept equipments 12 m long with a 208 mm diameter.

4.6. Washing station

Washing and decontamination of structural pieces which were flooded by an organic fluid - including the inside of the experimental-zone load-unload machine - are performed in the washing station.

The pieces are flooded or sinked in a warm methylnaphtalene bath. After being washed, the pieces are dried by a hot nitrogen circulation.

The used methylnaphtalene is purified in a distillation column. This column also provides pure methylnaphtalene for all the handling stations.

4.7. Active equipment storage

A station made of 63 sheaths of different sizes, installed in a shielded cave, is used for the temporary storage of active structural components (control rods, plugs, levelmeters, etc...).

4.8. Non-active equipment storage

This station is essentially used for the storage of contaminated handling tools. It has 48 storage positions.

4.9. ATFI air-lock

The ATFI air-lock connects the containment building with the structural materials hot laboratory ATFI. The tightness of the containment building is maintained during the lowering of irradiated equipment from the load-unload machines into the hot laboratory.

The limit characteristics of the devices that could be transferred, are :

length	:	8.65	m
diameter	:	243	mm
weight	:	3	t

4.10. Decay pool air-lock

This air-lock connects the containment building with the decay pools and is mainly designed for the transfer of irradiated fuel elements.

The tightness of the containment building is maintained when such a transfer is performed by one of the load-unload machines.

The limit characteristics of the equipments that could be transferred, are :

length	:	5.72	m
diameter	:	183	mm
weight	:	3	t

5. Decay pools

The decay pools, located outside the containment building, establish a connection between the containment building itself and the hot laboratory for irradiated fuel elements(ADECO). Their main purpose is the irradiated fuel elements storage in demineralized water.

It is presently foreseen to perform underwater operations, like visual examination, non-destructive testing, conditioning of irradiated fuel elements, before they will be transferred into the hot cells or loaded into a shielded container.

The feeding zone fuel elements, for example, are stored to decay for three months, before they can be loaded into the shielding container that will bring them to the reprocessing plant. In the meanwhile, their end fittings will be cut underwater. The experimental fuel elements can be stored underwater in leak-tight containers. If they were stored directly in contact with the water of the pool, they could eventually be examined or manipulated underwater.

Some water is permanently removed from the pools and circulated through a purification plant which includes two heat-exchangers, in order to maintain the water temperature at a constant level.

The characteristics of the decay pools are given on table 7.

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TABLE 1

MAIN CHARACTERISTICS OF THE DRIVER - ZONE LOAD-UNLOAD MACHINE

	Design characteristics	Operational limits
- Number of devices handled simultaneously	1	-
- Total weight of the machine	74,5 t	-
- Shielding - material	Lead + steel	-
- thickness	320 + 30 mm	-
- max. height of the active part of the fuel element	1500 mm	3100 mm
- Max. hoisting force	1000 kg	-
- Hoisting height	15 m	-
- Max. dimensions of the devices that could be handled in the flask		
- height	5,73 m	-
- external diameter	140 m	-
- Hoisting speed		
- low speed	0,96 m/min	-
- high speed	24 m/min	-
- Max. residual power evacuated by the flask cooling system	10,3 KW	-
- Cooling fluid	N_2	-
- Service pressure	4 ata	-
- Max. service temperature	180 °C	-
- N_2 flow	200 m^3/h	-
- Emergency cooling fluid	D20	-

TABLE 2

MAIN CHARACTERISTICS OF THE EXPERIMENTAL-ZONE LOAD-UNLOAD MACHINE

	Design Characteristics	Operational Limits (*)	Remarks
- Number of devices handled simultaneously	1	1	
- Total weight of the machine	173 t	-	
- Shielding - material	Lead + steel	-	
thickness	295 + 25 mm	-	
- Max. hoisting force	2 t	-	Could be raised to 3 t in special operating conditions
- Hoisting height	20 m	-	
- Max. dimensions of the devices that could be handled in the flask			
- height	9.35 m	-	
- external diameter	240 mm	-	
- height of the active part of the fuel element	1500 mm	2750 mm	
- diameter of the active part of the fuel element	90.4 mm	110 mm	
- Hoisting speed :			
- low speed	0.48 m/min	-	
- high speed	12 m /min	-	
- Max. residual power evacuated by the flask cooling system	9.8 KW	18 KW	
- Cooling fluid	N_2	-	
- Service pressure	4 ata	4.5 ata	
- Max. service temperature	180°C	-	
- N_2 flow	200 m^3/h	-	
- Emergency cooling fluid	methylnaphtalene	idem to H_2O to D_2O	

(*) The operational limits given are relative to the machine in its present state ; it is clear that these characteristics could be stretched by modifying certain equipments (hoisting speed, cooling blowers, heat exchangers, etc...)

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TABLE 3

MAIN CHARACTERISTICS OF THE ASSEMBLY-DISASSEMBLY STATION

	Present characteristics	Characteristics obtainable after internal sheath modification
- Max. active length to be manipulated (pits length)	6.57 m	8.23 m
- Max. total length to be manipulated (pits + cave height up to the crane bridge hook)	9.67 m	11.33 m
- Max. diameter to be manipulated	154/188 m	300 mm

TABLE 4

MAIN CHARACTERISTICS OF THE INTERMEDIATE STORAGE

	Design characteristics	Limit (*) characteristics	Characteristics after modification of internal sheath
Max. storable height	5847 m	6794 m	6794 m
Max. storable diameter of the active part of a fuel	90.4 mm	90.4 mm	110 mm
Max. storable diameter of the suspension plug of a fuel element	136 mm	156 mm	156 mm
Primary cooling fluid	Methylnaphtalene	Methylnaphtalene	Methylnaphtalene
Preheating max. temperature	200 °C	200 °C	200 °C
Service pressure at loading time	4 ata	4 ata	4 ata
Operation service pressure	4 ata	4 ata	4 ata
Primary fluid service temperature	200 °C	200 °C	200 °C
Max. removable residual power	118 KW (12 loaded pits)	Not yet determined	

(*) The limits given are relative to the installations in their present state ; these characteristics could be modified by installing new equipments specially designed for particular cases.

TABLE 5

MAIN CHARACTERISTICS OF THE DECAY PITS

	Design characteristics	Limit (*) characteristics
Max. storable height	9.28 m	11.50 m (1)
Max. storable diameter upper part	210 mm	240 mm (2)
" " " lower part	130 mm	164 mm (3)
Primary cooling fluid		
Pits n° 1 and 2	Methylnaphtalene	H_2O or Methylnaphtalene
Pits n° 3 to 5	Methylnaphtalene	Methylnaphtalene
Preheating	/	In course of study for pits n° 1 and 2
Service pressure at loading-time	1 ata	4 ata
Operating service pressure	4 ata	4 ata
Primary fluid service temperature	100 °C	not yet fixed
Removable residual power	6.5 KW per pit	not yet fixed

(*) see table 4

(1) Pit length

(2) Diameter to be handled with the load-unload machine

(3) Pit internal diameter

TABLE 6

MAIN CHARACTERISTICS OF THE PACKING STATION

	Design Characteristics	Limit (*) Characteristics
1) Storage containers		
Max. height available in the container	3781 mm	3900 mm
Max. diameter available in the container	90.4 mm	110 mm (new container)
Filling fluid	Methylnaphtalene	idem or H_2O following special request
Max. residual power of fuel	3.14 KW	-
2) Station		
Max. diameter to be cut (material / diameter)	Stainless steel/tube 20 x 27 mm	-

(*) See table 4

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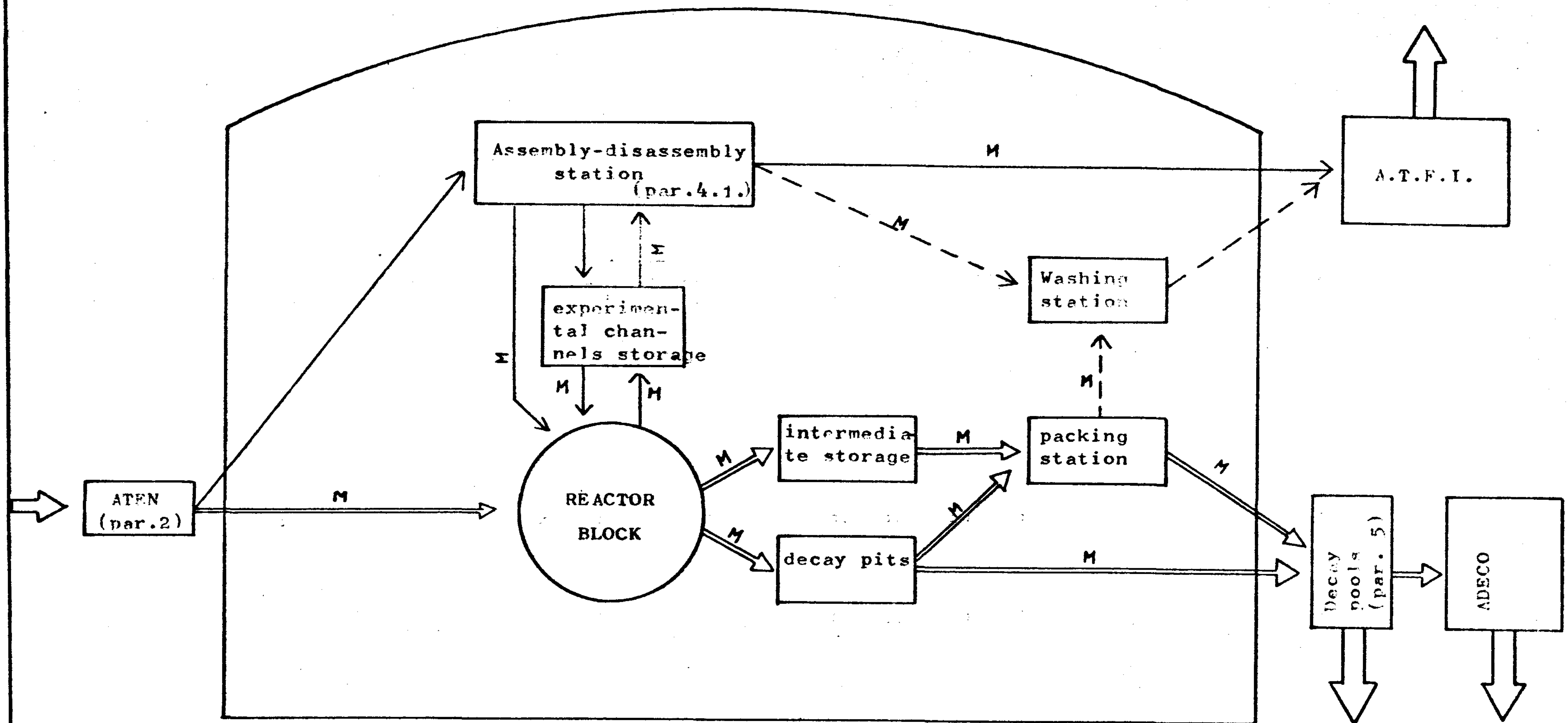
TABLE 7

MAIN CHARACTERISTICS OF THE DECAY POOLS

Number of pools	3
Volume of the pools	
n° 1 (containment building transfer air-lock)	50 m^3
n° 2 (storage)	250 m^3
n° 3 (storage, manipulations, ADECO transfer air-lock)	250 m^3
Water depth	8 m
Max. temperature of the water	30 °C
Average resistivity of the demineralized water	$10^6\ \Omega$ cm
Storage capacity	
pool n° 2 : experimental fuel elements	54
: feeding zone fuel elements	39
pool n° 3 : feeding zone fuel elements	20
Handling	
1 pool carriage, capacity	0.5 t
1 crane bridge, capacity	40 t

BLOCK DIAGRAM OF A TYPICAL HANDLING PROCEDURE FOR EXPERIMENTAL IRRADIATION DEVICES



Handling procedure for experimental fuel element

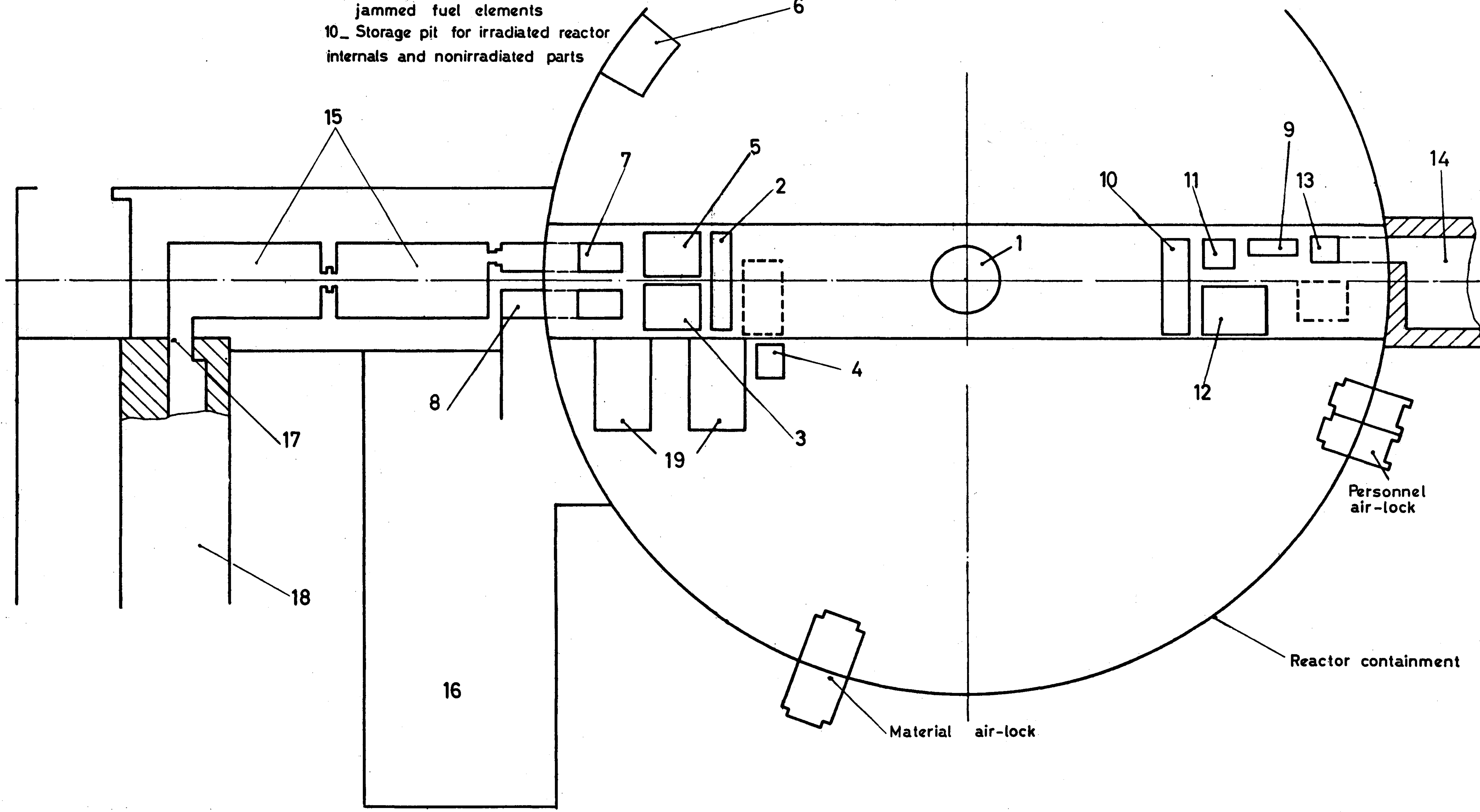
Handling procedure for experimental channel or fuel irradiation device

M Transport made by the load-unload machines (par. 3)

Fig. 1

Arrangement of handling stations

1. Reactor
2. Intermediate storage of orgel fuel elements
3. Packing station
4. Filling station for orgel fuel-element containers
5. Washing station
6. Control room for stations 2and3
7. Water-lock to decay pool
8. Air-lock for nonirradiated parts
9. Desactivation pitsfor orgel channels with jammed fuel elements
10. Storage pit for irradiated reactor internals and nonirradiated parts
11. Storage pit for pressure tubes
12. Dismantling station for orgel channels
13. Air-lock to hot laboratory for pressure tubes
14. Hot laboratory for pressure tubes
15. Decay pool
16. Workshop for nonirradiated parts
17. Water-lockto hot laboratory for orgel fuel elements
18. Hot laboratory for orgel fuel elements
19. Garage for charging/discharging machines



SECTION 5

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SECTION 5

HOT LABORATORIES

1. Introduction

The hot laboratories enable to treat all irradiated components before they leave the reactor plant.

There are two separate laboratories :

- A.D.E.C.O. (Atelier de Démantèlement des Eléments COmbustibles) for high activity fuel elements
- A.T.F.I. (Atelier des Tubes de Force Irradiés) for structural components.

The components discharged from the reactor core follow two different handling cycles (one for fuel elements, and the other for structural components), are introduced in storage cells, and after some time transported to the laboratory for dismantling, examination and testing. Once the treatment is concluded they can leave the reactor premises. The two laboratories are diametrically opposed with respect to the core and are located outside the reactor containment (see fig. 1 of section 4).

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2. A.D.E.C.O. (Atelier de Démantèlement des Eléments COmbustibles)

The laboratory takes the whole west wing of the plant, with a row of six cells in the middle. The cell row counts :

- a main dismantling cell on the upper floor, overhanging the decay pool and two cells of the lower floor,
- a neutrography cell, under the main cell,
- a waste disposal cell
- three spare cells.

The shielding has been conceived for a reference experimental fuel element, after 3 months decay in the decay pool (activity 100.000 cu, 1 MeV) in any point of the cells and at a distance of 1,50 m in front of the operator. The following reference datas have been assumed : 0,25 mr/h on the walls and lower part of the main cell, 2.5 mr/h on the upper part of the main cell. These rates are 10 times lower than usual to allow introduction of fuel elements with a shorter decay period.

All passages have been designed in order to remain within these values (see section of the main hall).

2.1. Main dismantling cell

The main dismantling cell is a shielded leak-proof hall under constant underpressure of 20 mm/H_2O, with inner steel plating covered with a decontamination paint coating. The steel tank has been set up before the concrete walls and is provided with several openings, rails for the 2 tons crane and heavy duty manipulator SERI B.300. Dimensions :

length : 10.40 m
width : 3.20 m
leight : 7.10 m

2.1.1. Equipment

a) Vision into the cells is afforded by 3 shielded windows designed on the principle of "delayed sealing" and ensuring a protection equivalent to that of the walls, made of 4 lead glass panes with oil joints.

b) Two master-slave manipulators CRL, extended reach, reinforced, and one heavy-duty manipulator SERI 2.300, double articulation, telescope hoist, lifting up to 300 kg in any position and resting on a trolley travelling along the cell ceiling.

c) A 2 tons travelling crane, which can be evacuated from the main cell, in case of accident, a jib crane with a 500 kg winch for the introduction in the neutrography cell.

d) The main cell is accessible from :

- the decay pool, for fuel elements, with lengths up to 5.80 m, diameter 200 m,
- a shielded door, with coupling device for the shell of the load container of the M.A.L., fuel elements with max. length of 1.70 m, max. diameter of 70 mm,
- the rear door, designed to receive the shielded intervention chamber
- a tobbogan for small size components
- an air lock for big size components (up to 6 m length) with a 600 mm opening; the operations can be executed under α protection,
- two openings leading to the waste disposal cell, diameter 365 mm and 220 m,
- shielded plugs giving access to the front and rear areas (diameter 130 mm),
- an upper shielding block (2 m x 1.40) with a staunch plate and circular opening for the extraction of the travelling crane and heavy-duty manipulator. Shielded containers may be introduced into the cell through the same opening.

e) Equipment and working tools :

- a plug extraction device for the packaging containers introduced from the air lock of the decay pool, closing the passage when not in operation
- eight storage pits of stainless steel with aluminium suspension and biological shielding plug. Each pit is cooled by the water of the decay pool, or by air circulation through the suspension (maximum flux 300 m3/h each)

- a cutting device for diameters of 300 mm^2 stainless steel, maximum blade opening 30 mm (for the upper extension of the fuel elements)
- a washing pit for fuel elements with discharge of the liquid to the active waste system
- an observation pit, in front of a shielded window, for direct observation, or inspection by spyglass or periscope. It is possible to displace the fuel element in front of the spyglass or periscope and stop it to take a photograph
- a dismantling rig for three separate operations :
  - longitudinal milling
  - transversal cutting
  - extremity milling
- a revolving spindle on the plate of the neutrography cell, designed to turn the fuel element for the neutrography, as it hangs on the jib crane of the main cell
- a set of self-acting grapples for the handling of components in the cell
- a lighting system composed of 10 security iode lamps with double envelops, 500 Watt each
- a power supply network (48, 127, 220 and 380 Volts alternating current) which can easily carry supplementary tools or devices
- a communication system with the inside of the cell
- a leak tight CLAVE periscope, magnifying power from 1,5 to 24 times and camera attachment
- a control panel placed under each window for remote control of the working tools.

2.2. Waste disposal cell

The cell is located under the main cell and protrudes into the rear area.

Dimensions:

length : 2,6 m
width : 3,2 m
height : 3,7 m

2.2.1. Equipment

a) Observation

Vision into the cell is afforded by two windows similar to those of the main cell

b) Each window of the cell is equiped with two manipulators M.S.-C.R.L. (see main cell 2.1.1. a). A 1 ton crane transports the components within the cell. The components are usually presented in front of the first window by the crane of the main cell, through an opening in the cell floor, and then carried to the evacuation station or to the transport container (through the ceiling plate).

c) The cell is accessible through :
- a shielded door, similar to that of the main cell,
- a ceiling plate, with adaptable opening, which allows to introduce safety containers from 200 mm to 330 mm diameter
- a passage to the next cell 4305, diameter 250 mm
- several shielding plugs

d) The cell has furthermore :

- a lighting system with 7 quartz-halogen lamps of 500 Watt
- two racks, one with two places under the main cell, and the other with four places under the ceiling plate, for depositing rods waste cans, etc.. before evacuation
- a power supply system (similar to that of the main cell)
- a communication system.

e) The cell is under constant underpressure of 2 g/cm^2.

2.3. Neutrography cell

The cell is located under the main dismantling cell and communicated with it through a passage closed by the revolving spindle (see main cell). The neutrography cell is provided with a shielding system which offers a biological protection comparable to that of the other six cells.

Dimensions :

width : 2,6 m
length : 3,2 m
height : 3,7 m

On the front side of the cell is door of cast iron, thickness 500 mm. At present the cell is being arranged in order to receive a neutron accelerator with a total flux of $\pm$ 10^{11} fast neutrons (for neutrography applications the thermal flux on the fuel element should amount to 10^5 - 10^6 n/cm^2).

2.4. Spare cells

After the waste disposal cell there is a row of spare cells, which respond to the same specifications.

2.4.1. Cell 4305

Dimensions : 3,20x4,10x3,60. The cell is provided with one operation unit and passages for conventional equipment (windows, manipulators, ceiling plate, plugs etc...).

A rectangular well (1,10/2,10 m) on the floor offers space for a machine which has to be places on a relatively low level.

2.4.2. Cell 4306

Dimensions : 3,20x7,10x3,60 m. Provided with two windows and passages as the preceding and two reactangular openings for communication with the basement.

2.4.3. Cell 4307

Dimensions : 3,20x3,15x3,60. Same equipment as the cell 4305. The three spare cells are communicating with each other and with the waste disposal cell by means of a circular opening of 250 mm diameter.

3. **A.T.F.I.** (Atelier des Tubes de Force Irradiés)

Consist of a great shielded cell, with three sections :

- observation cell and air lock giving access to the reactor containment

height	:	11,5 m
length	:	3,26 m
width	:	4,86 m

- sectionning cell for pressure tubes

height	:	11,5 m
length	:	3,6 m
width	:	4,76 m

This cell is separeted from the observation cell by a concrete wall (thickness ± 72 cm) taking 3/4 of the width and 4/5 of the height and leaving free space for an access corridor.

- testing cell

height	:	10,16 m
length	:	4,86 m
width	:	4,90 m

This cell is separated from the sectionning cell by a concrete wall

- the whole of the three cells has an "L" shape and the concrete walls (density 2,3 g/cm^2) have a standard thickness of 1,10 m.

The dosis on the outer surface of the wall for a source of 7000 Cu, 1 MeV is lower than 0,5 mr/h.

- The walls are covered on both sides with a decontamination paint coating
- The cell block is leak-tight and submitted to a dynamic underpressure of 1,5 g/cm^2.

3.1. Observation cell

Cell for the inspection of inner and outer surfaces of a pressure tubes by means of TV cameras with remote control. The cell has no observation window. The operations are followed by means of two TV cameras : one on the trolley of the travelling crane, and the other on the travelling crane of the heavy duty manipulator; both cameras are used for the three cells and can be displaced along a rail.

3.1.1. Equipment

Television cameras CSTA with swinging eye, attached lighting system and automatic focusing device. The camera is connected to a power cable rolled on a drum, and can travel on a length of 6 m.

The minimum inner diameter examined by the camera is 60 mm.

The lighting system consists of 6 Iodine lamps.

The observation cell is accessible through :

- the air lock for irradiated pressure tubes
- a double ceiling plate for both sectionning and observation cells
- the corridor from the sectionning cell to the observation cell

The cell disposed of the 2 tons crane and heavy-duty manipulator in common with the other cells.

There are two passages for a CLAVE periscope.

3.2. Sectionning cell

The cell has one working position with one window on the lower side identical to those of the ADECO laboratory and two M.S. - C.R.L. manipulators extended reach

It is under constant underpressure of - 1,5 g/cm^2.

3.2.1. Equipment

The cell has :

- a cutting machine for pieces of 1 mm (aluminium) to 8 mm (thickness stainless steel) and diameters between 65 (inner) and 200 (outer)
- a 2 tons crane common to the three cells (hoisting height 9,7 m)
- a passage for the "CLAVE" periscope
- a cast iron rear door 1 x 2,10 m
- a double ceiling plate 4 x 2 m
- a rear corridor taking the whole heigth of the cell.

3.3. Testing cell

The testing cell is equiped with three working points with shielded windows and two C.R.L. manipulators each (same model as in A.D.E.C.O.) reaching any point of the cell.

The cell is under contant underpressure of - 15 mm/H_2O.

3.3.1. Equipment

- One heavy-duty ALCATEL manipulator for the three cells travelling on a rail along the main axe, in common with the 2 tons crane (hoisting power 150 kg with the arms in vertical position and 100 kg in any other position), an additional block with a hoisting power of 500 kg and a travelling length of 10 m.

- A tightness test rig for the examination of connecting points of irradiated pressure tubes, with a maximum length of $\pm$ 1.140 m and diameter of 92 to 124 mm (92 to 99 mm and 110 to 124 mm)

- A burst test ring for pressure tube sections (possibility of high precision, 300 kg/cm^2). The sections must be 1140 mm long, with a diameter of 92 to 98 mm.

- A television set with two cameras mounted on a revolving post; one on the travelling crane and the other on the crane of the manipulator. Both cameras are connected to a central unit, provided with two televisions screens (working position of the sectionning cell, and three working positions of the testing cell).

- A setof self-acting grapples for component handling (see ADECO)

- A communication system (see ADECO)

- Two tobbogans for small-size components (see ADECO)

- Several passages :
  - a shielded door
  - three ceiling plates, one designed to be coupled with the transport container of the ESSOR plant (see ADECO)
  - a passage leading to the basement with a plug closed by a vinyl bag
  - several openings with shieldings plugs (spare passages)

- A power system with consoles and control pannel, for later utilisation of the area as testing cell

- A lighting system with ten lamps of 500 Watts (see ADECO).

4. Transport container

There are 5 transports containers of three differents models :

- two containers for waste
- two containers for fuel rods
- one container of the **L.M.A.**

4.1. Container for waste.

The container can be charged and discharged vertically, with an attached hoisting system mounted on the upper plate and composed by : winch, stainless steel cable, and grapple. The container can be dissassembled in three sections :

- the upper plate with the hoisting system
- the container body
- the bottom, closed by two shielding doors

The container is not tight and can be used only on the premises of the Research Center.

Specifications :	- Shielding	:	200 mm Pb
	- Inner diameter	:	370 mm stainless steel
	- Inner useful length	:	± 890 mm

4.2. Container for fuel rods

Same structure as the waste container

- inner diameter : ± 220 mm stainless steel
- inner useful length : ± 1815 mm

The grapple of the container may be employed also fo the storage pit of the fuel element waste (fuel rods).

4.3. Container of the L.M.A.

The container can be charged and discharged horizontally by means of a shell whose movement is controlled from the rear side of the container.

When the transport container is placed against the door of the main ADECO cell, the shell is inserted in the cell with a leak tight system; when the inner part of the shell protudes into the main cell it is possible to make the substitution (model : RAGUENEAU-LA CALHENE-FRANCE).

The L.M.A. transport container is used to carry fuel element rods from ADECO to the Medium Activity Laboratory of the Metallurgy department.

Specifications :	- Shielding	: 200 mm Pb
	- Inner diameter	: ± 90 mm stainless steel
	- Inner useful length of the shell	: 1650 mm
	- Inner diameter of the shell	: ± 80 mm

The shell is provided with a lead cylinder at both end, to protect the operators during the handling phase (L = 250 mm and 40 mm).

Studies are carried out on this container in order to obtain the agreement for transportation outside the Research Center area.

5. Equipment under planning or under development

5.1. A.D.E.C.O.

5.1.1. Glycol-test

The glycol-test device detects fuel elements cladding failures before and after sectionning. It detects gas escaped from the cladding of a fuel element in a vacuum container filled by a fluid with low vapour tension, by following the bubbles.

It shall be possible to test fuel clusters 1650 mm long with 110 mm diameter and "I" head, corresponding to the reference experimental fuel elements. With minor changes it will be possible to test any cluster with the same maximum dimensions, but with a different head.

Instead of the cluster, it is possible to test a basket with one or several fuel rods.

Thermip should be employed with ORGEL elements, but glycol and other fluids may also be used ; in this case feeding and discharge operations are executed outside the cell.

5.1.2. Neutrography

The cell 4303 is provided with an aluminium channel for the introduction of the components to be examined. It was conceived for X-rays, but after a comparative study of X-rays and neutrography, the latter has been chosen, in order to obtain a representative image of the whole cluster or of single rods before dismantling.

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The equipment should supply a flux of 2×10^{11} n/sec for more than 200 hours, with possibility of later improvements. The thermal flux of 5.10^{5} n/cm^{2}/sec to 10^{7} n/cm^{2}/sec is sufficient for the examination of fuel elements such as the reference fuel element.

The observation of fuel rods with diameters up to 40 mm allows to detect any modification occured in the cladding.

5.1.3. Metrology

We intend to equip the waste disposal cell with a metrology rig for diameter, length and bowing measurement of fuel clusters and fuel rods.

The measurement accuracy of the rig, operating on an optical principle, should be as follows :

$\pm$ 0.1 mm for the length (max length 1650 mm)

$\pm$ 0.01 mm for the diameter (0 to 200 mm)

$\pm$ 0.05 mm for the bowing

Should the budget be available, the cell will be ready during 1969.

5.1.4. Spectral study of fission products

The possibility of setting up a γ spectroscope is under consideration. It would allow to examine fuel rods 3 m long and should be equipped with a Sodium iodide detector and a 400 channels analyzer. In the future, according to the requirements, it would be possible to replace it by a Ge-Li detector and a 200 or 400 channels analyzer.

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5.2. A.T.F.I.

5.2.1. Hot burst rig

The rig, at present under construction, works on the same principle as the cold burst rig, and permits the examination of the bursting conditions of a pressure tube at 400° C under axial and radial gas pressure, of 3 mm tickness and 70 cm length. The burst can be slow or fast (after a short creep of 100 hours) and the testing pressure can reach 400 kg/cm^2. With slight modifications of the elements heads, it would be possible to admit also other diameter and thickness values.

5.2.2. Metrology of pressure tube sections

It is expected to set up a metrology rig for precision measurements of inner diameter and thickness of pressure tubes from 50 cm to 1 m length, provided with a supersonic head detecting any increase in micro faults density due to irradiation in the reactor (punctures, corrosion, erosion, etc...)

5.2.3. Creep tests on samples

The creep tests on samples might be executed in the Medium Activity Laboratory of the Research Center. The sectionning machine is being assembled in the A.T.F.I. Laboratory. The tube sections coming from the machine are then transported by means of a lead transport container to the testing laboratory.

6. Decontamination and intervention hall

A decontamination hall with glove-boxes, supersonic decontamination tanks, hoods, heating tanks, etc... is annexed to the hot laboratories. In the ADECO laboratory it is possible to connect to the cells an air tight traveling lock provided with a biological shielding of 100 mm steel.

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7. Decontamination and waste disposal service

7.1. The hot laboratories may be assisted by the decontamination Service of the Research Center which has all necessary equipment for intervention and decontamination, namely :

- 2 small intervention trucks
- 1 heavy intervention truck
- 1 workshop truck
- 1 decontamination laboratory with :
  - . 2 dismantling hoods,
  - . 1 sandblasting and gravel blasting equipment,
  - . several decontamination tanks,
  - . one device for ultrasonic decontamination,
  - . testing and decontamination services, etc...

7.2. Waste disposal

Wastes coming from the hot laboratories are treated by this service. Several methods are employed : tar canning for low activity waste and muds obtained during chemical treatment of effluents ; concrete canning for medium activity solid effluents ; deposit in storage pits for high activity waste with every possible caution against contamination transfer and irradiation.

8. Storage in the decay pool

The decontamination-Service is provided with a decay pool conceived in order to receive the storage containers of the ESSOR fuel rods.

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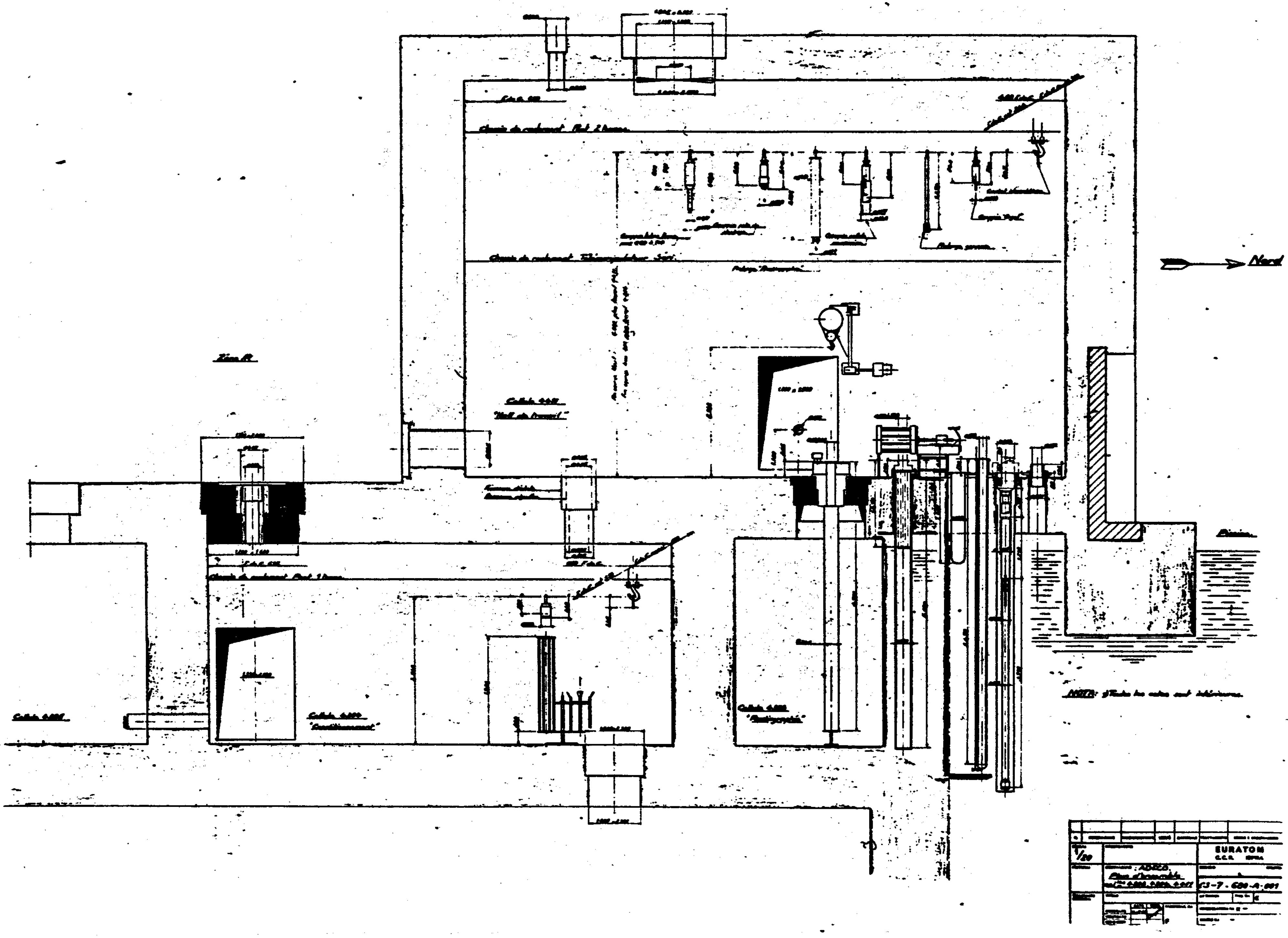

Nord
Zone B
Piscine
NOTE: Toutes les cotes sont intérieures.
EURATOM
C.C.R. ISPRA
ADECO
Plan d'ensemble
C3-7.600-A.001
1/20

SECTION 6

MEDIUM ACTIVITY LABORATORY

INDEX

MEDIUM ACTIVITY LABORATORY

1. Introduction

The medium activity laboratory of the Metallurgy and Ceramics Division of the Ispra Research Center does not belong to the ESSOR plant, but is a complementary facility for the study of fuel and nuclear materials behaviour under irradiation, mainly in the field of metallography.
The ADECO laboratory of the ESSOR plant sends to the LMA, by means of the "transport container of the LMA" (see transport containers and hot laboratories), the components of the irradiated fuel elements dismantled in the main ADECO cell.

The LMA laboratory has an U-shaped form with one entrance cell, or concrete cell, and two rows of lead cells (see plan view).

The following materials will be handled in the cells : UC, UO_2, SAP, stainless steel and Zircaloy. The operations and examinations executed in the cells are :

- dismantling or disassembling of a fuel rod or of a fuel assembly after irradiation ;
- sample treatment for metallographical, physical and chemical examinations ;
- determination of fission gases formed during irradiation (puncture-test) and during thermal post-irradiation treatments ;
- measure of "gamma" activity of fuel elements for burn-up determination ;
- dimensional measurements ;
- macro and micro examinations, including sample coating and treatment
- density determination
- thermal and electrical conductivity measurements
- determination of mechanical properties such as hardness, tensile stress and resilience
- thermal treatments up to 2.000 °C.

2. Entrance cell or concrete cell

The walls are made of baritic concrete, density 3,4 , thickness 1 m. The biological shielding has been designed in order to reduce activity of a punctual source of 22.000 Ci (1 MeV) at 30 cm from the inner wall surface, to 2,5 mr/h in the inner space of the cell.

2.1. Equipment

The cell is provided with :

- three windows, each with two manipulators MS "extended reach" M. 9 and P.V.C. sleeves ;
- a 1 ton travelling crane (E.R.T.N.) ;
- a heavy duty manipulator (E.R.T.N.) for 1000 kg ;
- a working bench with vertical drilling-machine, remote control ;
- a working bench with a vertical cutting-machine for cladding removal and a cutting-machine with sanding disks ;
- a milling-machine for longitudinal cutting of fuel element cladding ;
- an alpha-tight stereoscopic periscope for each P.V.C. sleeve ;
- a fission gas sampling device ;
- a gamma-scanning device ;
- a rear cast iron door with vinyl bag;
- a rear thimble with sliding doors and coupling device for the shell of the lead container, i.e. LMA transport container of the ADECO laboratory ;
- three storage pits for fuel elements with cast iron plugs ;
- a ceiling plate ;
- cold lighting by horizontal lamps lodged in the cell ceiling ;
- passages for electrical cables, air, etc... ;
- a general control panel on the front side of the cell ;
- a ventilation system with filters and prefilters with an under-pressure of $\pm$ 20 mm/H_2O .

3. Lead cells

The wall thickness of 15 cm allows to reduce activity from a punctual source of 150 Ci (1 MeV) at 30 cm from the inner wall, to a dosis under 2,5 mr/h.

- each cell is equipped with M. 7 manipulators or remote handling tongs. The vision in the cell is afforded by windows consisting of lead panes. Illumination is supplied by quartz lamps above the windows.

- The cells are equipped with an inner alpha-tight envelope, and are under constant under-pressure. Each cell has an absolute entrance filter and an absolute extraction filter.

- Transportation from cell to cell departing from the entrance cell is made by means of a trolley running along an "alpha" gallery under the floor of each cell. The trolley can be raised to the floor level through an opening provided with an elevator ensuring a leak-tight connection with the cell.

3.1. Equipment of the lead cells

The position of the cells is shown in the joint figure. There is :

a) a row of lead cells for metallography

- 1st cell : treatment of samples coming from the entrance cell
- 2nd cell : cleaning of samples of fissionable materials
- 3rd cell : cleaning of samples of non-fissionable materials
- 4th cell : electrolitical or chemical cleaning of the samples
- 5th cell : microscope examination

b) a row of lead cells for physical tests

- 1st cell : thermal conductivity measurement (in project)
- 2nd cell : electrical resistivity measurements
- 3rd cell : density measurements
- 4th cell : dilatometry measurements
- 5th cell : metrology with a precision of 5 microns

c) a row of lead cells for mechanical testing

- 1st cell : Vickers, Brinell, Knoop and Rockwell hardness measurements
- 2nd cell : tensile tests up to 5 tons
- 3rd cell : resilience measurements with a 5 kg pendulum Samples model Izod, section 5 x 10 mm, provided with a notch. A set of Adamel ovens and a freezer unit allow working temperatures from -150 °C to +600 °C
- 4th cell : thermal treatment in 2 ovens under vacuum up to
  5th cell : 2000 °C

d) A row of lead cells for the study of fission gases

- 1st cell : thermal treatment in an induction furnace under vacuum
- 2nd cell : circuit for fission gases measurements.

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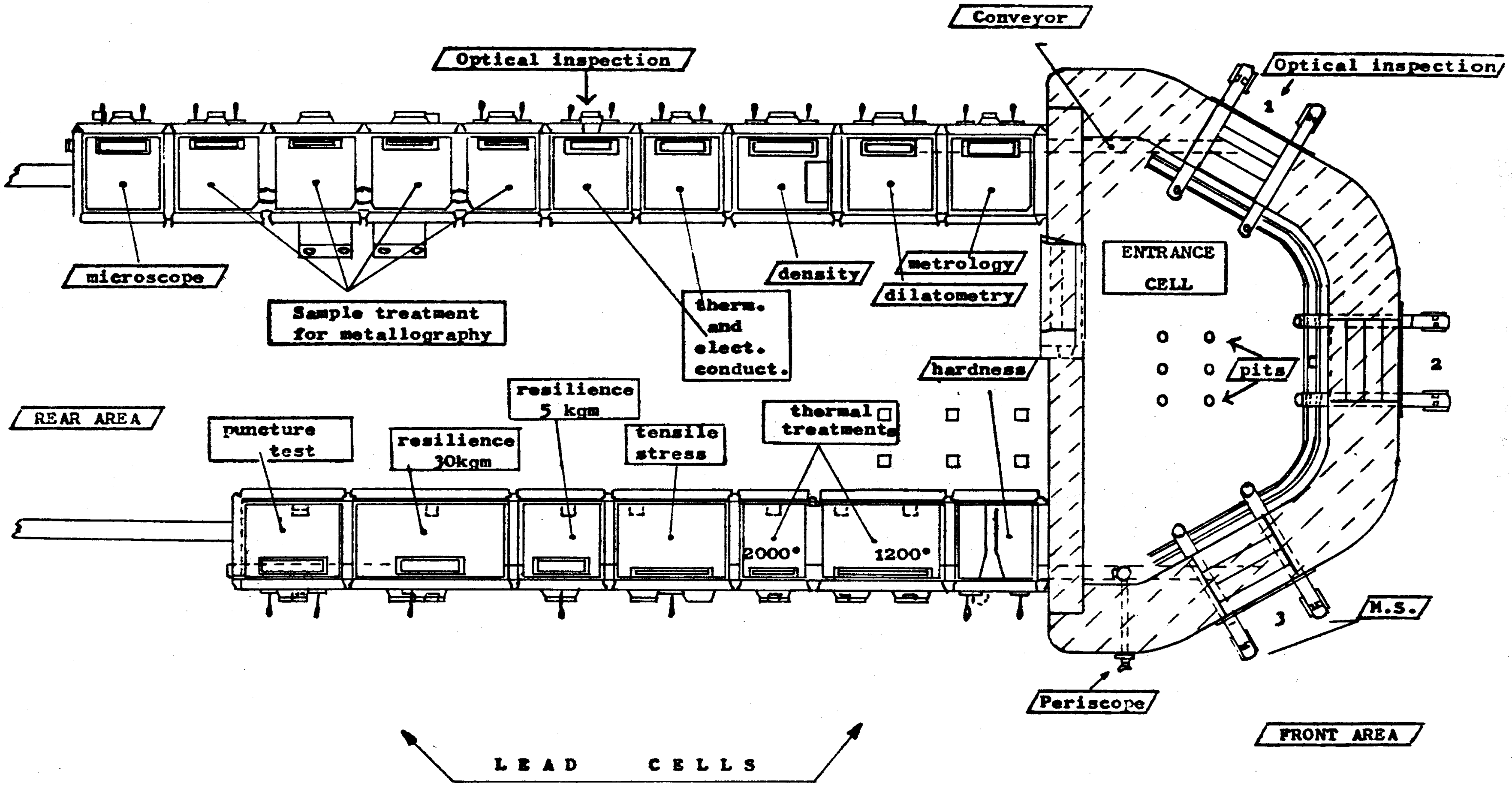

MEDIUM ACTIVITY LABORATORY (L M A)

Section 7

DATA LOGGING AND PROCESSING (TIS)

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DATA LOGGING AND PROCESSING (TIS)

ESSOR is continuously monitored by an integrated data processing system based on two digital computers. Besides the reactor informations, a certain amount of experimental datas may be fed into the computers. For that reason, the following chapter devoted to the data processor unit called TIS might be of interest to the experimenters.

1. Main characteristics and operation

1.1. General observations

The TIS is a unit which takes charge of safety of the reactor as far as thermodynamical measurements are concerned. In more detail, it has the following tasks :

- control of parameters and initiation, if necessary, of a safety action,
- testing the proper functioning of the TIS itself,
- detecting the order in which incidents occur,
- displaying and logging measured and calculated values on request,
- logging general information.

The TIS can order alarms, power reduction, reactor shutdown and special actions by means of automatic circuits associated with various parts of the plant.

Except as regards neutron measurements, it represents the "measurement - logical circuit for safety actions - control circuit" link in the reactor safety system.

1.2. Parameters analysis and safety actions

The TIS compares the value of each parameter to one or more reference levels. Should a level be exceeded, the TIS gives an order which may initiate an alarm or a safety operation. For certain "main" parameters, there are several measuring chains. A safety operation is initiated only in the event of a logical combination of excess values. In order that the operator may know the trend preceding an excess, the TIS memorizes the ten most recent values of the corresponding parameter, which appear on a type-writer at the moment the reference level is exceeded.

The scanning time, the number of values memorized and the memorization time are fixed in relation to the plant intended response-characteristics in the event of an incident involving the parameter in question.

The parameters processed may be grouped as follows :

- main parameters,
- auxiliary parameters,
- calculated parameters.

A. Main parameters (figs.2)

Most of the main parameters are measured by three independent chains in order that sufficient information may be obtained in case of fault on one chain.

There are three reference levels : S1, S2, S3.

The actions initiated are the following :

- alarm,
- reactor power reduction,
- reactor scram,
- reactor scram and action on certain circuits, in particular cooling

Generally speaking, if S1 or S2 or S3 is reached by one of the three chains, the computer which is the central unit of the TIS gives an alarm signal as long as the excess continues ; a further comparison is made with the upper level if necessary, and the computer memorizes the average of the three values.

If S1 or S2 or S3 is reached by at least two chains the computer orders respectively an alarm, a power reduction, or a scram, and memorizes the average of the values.

S3 is reached by two chains at least and if the S3 level is also reached by another logically correlated parameter, a special supplementary action can be initiated.

If on the other hand no reference level is reached, the computer memorizes the average of the three values at every p th measurement cycle, p being dependent on the parameter. At the same time the oldest memorized value is dropped.

Each time an alarm signal is given, the following indications are printed :

- on the "stored values" teleprinter : time, parameter address, memorised values ;

- on the "fast-speed faults" or "slow-speed faults" teleprinter, according to the scanning speed : time, parameter address, value of the excess, until the fault disappears (unless the operator requests the cessation of the printing).

Whenever a safety action is requested the following indications are printed on the "safety actions" teleprinter : time, parameter address, action requested.

B. Auxiliary parameters

The auxiliary parameters are measured by one chain only. There is only one reference level and the only action which can be initiated is an alarm

The value of the parameter is memorized at every p^{th} measurement cycle. In the event of an excess the "memorized values" teleprinter prints the time, the adress of the measurement, the memorized values and the reference level. The excess value is printed on the "slow-speed faults" teleprinter with the time and the parameter address until the fault disappears, unless the operator requests the cessation of the printing.

C. Calculated parameters

In addition to the comparisons to reference levels and the average calculations which it carries out normally, the TIS has to compare measured values with one another and in some instances to make special calculations, particularly in connection with visual notification of thermal power determination of organic coolant flow, supervision of neutron chains, and burst-slug detection.

A few particular actions still need to be mentioned :

- burst slug detection :
  The TIS carries out all the detector-control operations, the activity measurements and the trend calculations for all the burst-can detection assemblies.

- Dust and gas activity
  The TIS executes the orders for reading sampling point numbers and measuring their instantaneous and possibly deferred activity ; these orders come from the automatic device connected with the display keyboard.

  The operator may request the TIS to repeat the readings automatically for a certain number of points (collective sampling) or to repeat automatically the readings for a particular point (follow-on-method).

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Finally, the TIS has to carry out certain corrections and linearizations of the parameters to be printed or displayed visually.

Corrections referring to temperature measurements by thermocouples takes into account the effect of the cold welding temperature, as measured by a resistance probe and scanned among the other analogical parameters.

The drift of the amplification-conversion system is periodically calculated by programme from measurements of two stable reference voltages associated with the amplifier, whose computer stores theoretical values.

The comparison of the parameters to their reference levels is made with unprocessed values, i.e. values which have been neither linearized nor corrected. The stored reference-levels are therefore inversely corrected and adapted immediately upon introduction, and periodically thereafter if necessary, in order to restore them to the unprocessed condition.

The reference levels are introduced and modified by means of the service teleprinter associated with the control computer.

1.3. Test of the working of the TIS itself

Parity control : This control is effected systematically for every exchange of information between the arithmetical bloc and the memory of the transfer unit. The detection of a parity error results in the emission of an internal interruption signal which immediately stops the computer. The auto-control tests described below can therefore not be carried out and there is consequently a switch-over to the standby computer.

Auto-control test : This test carried out every 500 ms on the receipt of an interruption signal produced by one of the two timers. The test takes 30 ms. The programme tests first the presence of a "numerical inputs-outputs error" (by programme an output relay is closed or opened and its position is checked in return on an input line). If this error signal is present the computer stops. If not, the programme tests successively each instruction of the central unit (instructions for storing in memory,

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for arithmetical operations and logical operations, for the displacement of memory zones). If the auto-control programme is carried out correctly, it concludes with the emission of a signal to the auto-control circuit associated with the computer. This signal, received every 500 ms by the circuit if the computer is not out of order, prevents a switch-over. If the signal is not received , the auto-control circuit switches to the stand-by computer.

Test of the working of the conversion system

The two reference voltages existing in each group of 16 main parameters and in each group of 96 auxiliary parameters are scanned like the other parameters of the group and their value is compared to their previously-memorized theoretical value. In addition to measurement corrections, this arrangement makes it possible to localize a faulty amplifier in the analogical chains. The exploitation of the measurement signals passing through this amplifier is then forbidden by programme and the fault is indicated on the "safety actions" teleprinter. Simultaneously the computer considers the faulty measurement to have passed the most dangerous level. If errors are detected on at least two rapid (1 s or 2 s) groups, the computer orders a switch-over to the second converter.

Drum test

If the switch to the second converter does not result in an improvement, the fault may lie in the drum. A power set back of the reactor is then triggered-off, and the most important parameters enter directly the working memory.

In addition a parity check is performed during read-out of the information stored on the drum ; the parity bit is provided by the converter. Failure of the check has the same consequences as in the preceding case.

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"Timer" system test :

Functioning is checked by the computer which receives the programme signals (1 s, 10 s) and compares their time of appearance with the reference times obtained by calculation. If there is a discrepancy, the computer orders a switch-over to the stand-by unit.

The signal which occurs every 500 ms is controlled electronically. If a fault is detected, another signal is emitted in due time and the computer orders a switch-over to the stand-by unit.

Stand-by unit failure :

If a stand-by unit itself fails at a time when the normal unit cannot be put back into service, a power set back is triggered off.

Check on measurement chains :

A broken wire, a short circuit or a transmitter fault originate a zero signal. If a measurement chain gives a signal below a minimum reference level applying to all the chains, an alarm is given.

For parameters measured by three chains, the computer considers the faulty measurement to have passed the scram level.

1.4. Other functions of the TIS

Detection of the order in which incidents occur

In order to detect the sequence of incidents, the computer supervises the positions of about 100 contacts. Changes of position are considered simultaneous if the time interval separating them is less than 0.1 s, this being the time between two successive scanning periods. Changes are recorded on the "safety actions" teleprinter in the order in which they occur.

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Display and logging of values on request :

The request keyboard enables the operator to request the value of any parameter entering or calculated by the TIS. This one then appears on a numerical display case. A key on the keyboard enables the operator to require this value to be printed on the teleprinter. This request switches off the display signal. It is possible to require the simultaneous printing of 20 measurements. Another key can stop the printing of any measurement.

Logging of general information

This is done by the following machines :

- two punched-tape machines
- some analogical logging units. The system includes three analogical outputs obtained by decoding 3 x 9 binary numbers,
- ten teleprinters which perform the following tasks :

    - reference-levels introduction and test-logging,
    - memorized values logging,
    - fast logging of faults,
    - slow logging of faults,
    - safety-actions logging,
    - burst-slug logging,
    - routine general logging,
    - logging readings at operator's request,
    - delayed calculated information logging,
    - radio-protection faults logging,

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2. Principal structural characteristics

The TIS is composed of three structural assemblies :

- input system,
- central unit,
- output system

Figure 1 shows the general set-up.

2.1. Input system

A. Scanning unit

This consist of filters and electromechanical relays followed by electronic switches. With the "low-level" signals a differential amplifier is inserted between the relays and the switch associated with these signals. The signals are at present distributed as follows :

- 8 groups of 16 parameters scanned every second
- 5 groups of 16 parameters scanned every two seconds
- 6 groups of 96 parameters scanned every twelve seconds
- 2 groups of 64 parameters scanned every twelve seconds
- 1 group of 32 parameters scanned every twelve seconds

The three chains measuring the main parameters are connected to different groups, so that a fault in an amplifier or an electronic switch affects only one of the three chains.

For one group scanned every two second and three groups scanned every twelve seconds, the scanner and amplifiers are inside the containment of the reactor. For the other groups, they are in the room of the central units.

For each group, two inputs are reserved for stable reference voltages designed to control the entire analogical chain.

The output of the electronic switches is connected to the analog-digital converter.

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B. Analog-digital converter

The 0÷10 V signals emitted by the electronic switches are converted into binary signals (10 bits + sign) which are passed to the analogical tracks of the magnetic drum at the right moment, the scanning and conversion unit being synchronized by signals from the magnetic drum. For safety reasons the converter is duplicated.

C. Magnetic drum

This external memory stores the following informations :

- numerical measurements or measurements converted into numerical informations,

- reference levels and normal control programme,

- the memorized values every p measurement cycle,

- all the programmes which ensure the normal control.

The logging time is independent of the processing time. The drum is switched automatically into the second computer when the first computer develops a fault, in order to ensure the maximum continuity of control. Since the drum itself is very reliable in operation, it has not been duplicated.

D. Pulse inputs

Before being fed into the computer the pulse trains are taken over by the timer, an organ which is duplicated for reasons of safety Piloted by a quartz time-base, it makes all the necessary signals for commanding the DRG feeding zone devices (counters and revolving drum) and for measuring various activities by pulse counting. It also makes all the programme signals (0.1 s, 0.5 s, 1 s, 2 s).

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E. "On-off" inputs

The programmes are normally fed in by a fast punched-tape reader (300 Char/sec.)

F. Reference levels input

Done by the first teleprinter mentioned above (in 1.4.) which is thus a two-way link with the central unit.

2.2. Central unit

Since this unit is duplicated for safety reason, the information is processed by two CAE 510 computers. Each computer has a ferrite core working memory of 24,000 words of 18 bits. The access time to a stored word is six microseconds (reading-writing)

The method of using the computers can be summarized as follows :

- computer 1 is in charge of control and safety,
- computer 2 as a stand-by device,
- if computer 1 fails, computer 2 is connected to the magnetic drum in order to take over the control and safety programme. The numerical input and output units and the teleprinter control circuit units are also switched over (fig. 1)

While computer 1 is on line computer 2 stores the following informations in its memory :

- the computer test programme,
- a monitor programme whose purpose is to call the control programmes from the drum when computer 1 is switched over to computer 2.

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2.3. Output system

A. "On-off" outputs

These feed solid state logic blocks for control or indication. In order to avoid all interference a decoupling has been inserted between the feed to these systems and the TIS. Scram and special-action lines are duplicated.

B. Teleprinters

These are ordinary machines with short (28 cm.) or long (72 cm.) carriages.

The indications on the logging sheets have the following characteristics :

- the time is composed of six numerical characters,
- the addresses have four alpha-numerical characters,
- the parameter values are printed to three significant figures.

Teleprinters which have to log several types of parameter, do print simultaneously the address and the unit in which the parameter is being measured.

C. Experimental outputs

These consist of a puncher (100 char/sec) and three analogical outputs. A second puncher is associated with the stand-by computer and a third is in reserve.

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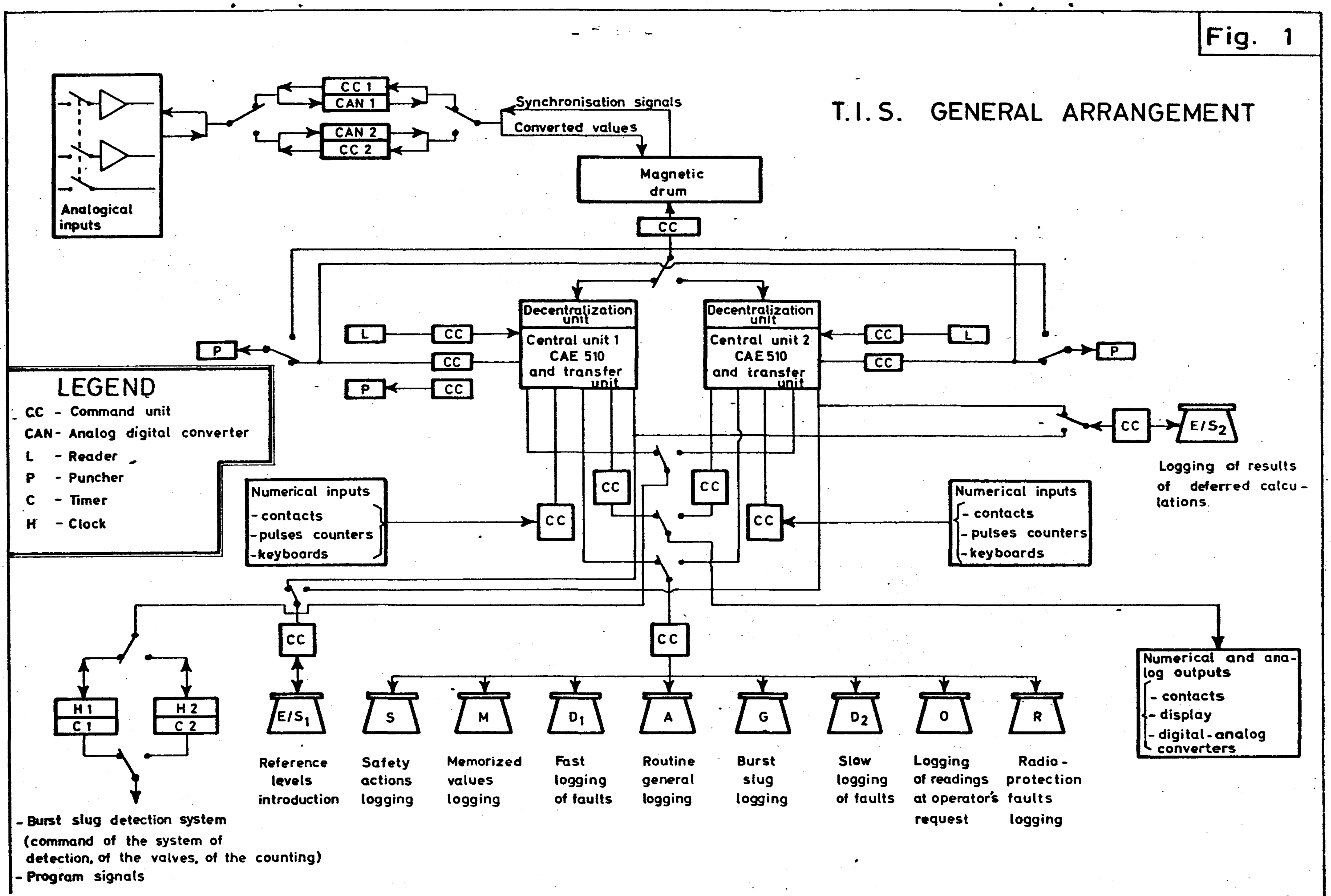

Fig. 1
T.I.S. GENERAL ARRANGEMENT
Analogical inputs
CC 1
CAN 1
CAN 2
CC 2
Synchronisation signals
Converted values
Magnetic drum
CC
Decentralization unit
Central unit 1 CAE 510 and transfer unit
Decentralization unit
Central unit 2 CAE 510 and transfer unit
L
CC
P
CC
P
CC
CC
L
CC
P
LEGEND
CC - Command unit
CAN - Analog digital converter
L - Reader
P - Puncher
C - Timer
H - Clock
Numerical inputs
- contacts
- pulses counters
- keyboards
Numerical inputs
- contacts
- pulses counters
- keyboards
CC
E/S2
Logging of results of deferred calculations.
Numerical and analog outputs
- contacts
- display
- digital-analog converters
H 1
C 1
H 2
C 2
E/S1
S
M
D1
A
G
D2
O
R
Reference levels introduction
Safety actions logging
Memorized values logging
Fast logging of faults
Routine general logging
Burst slug logging
Slow logging of faults
Logging of readings at operator's request
Radio-protection faults logging
- Burst slug detection system (command of the system of detection, of the valves, of the counting)
- Program signals

/ Fig. 2 / Exemples of T.I.S. inputs leading to a safety action (main parameters)

Circuit	Parameter	Address	No. of param.	No. of chains	Scanning cyc. takes	Law of interven.	Action: Alarm	Action: PR	Action: SC	Action: Special actions
Multiple loop	Temperature (T)	Channels outlet	8	24	2s	1/3 $T > S_1$	x			
						2/3 $T > S_2$		x		
						2/3 $T > S_3$			x	
		Secondary outlet main exchanger	1	3	2s	1/3 $T > S_1$	x			
						2/3 $T > S_2$		x		
						2/3 $T > S_3$			x	
	Pressure (P)	Secondary expansion vessel	1	3	1s	1/3 $P > S_M$	x			
						1/3 $P < S_1$	x			
						2/3 $P > S_2$		x		
	Flow (F)	Reactor outlet	1	3	1s	Calculation of $P/k\ F_{tot} = \varepsilon$				
						1/3 $\varepsilon > S_1$	x			
						2/3 $\varepsilon > S_2$		x		
						2/3 $\varepsilon > S_3$			x	
	F_{en}	Channel inlet	8	8	1s	Comparison inlet-outlet				Accelerated memorization of the most important measurements for 20 sec.
	F_{sn}	Channel outlet	8	8	1s	$\frac{F_{en} - F_{sn}}{F_{en}} = \varepsilon_n$ $\varepsilon_n > s$				
						Calculation of $P/k\ F_{en} = \varphi_{en}$ $\varphi_{en} > S_M$	x			
						and $P/k\ F_{sn} = \varphi_{sn}$ $\varphi_{sn} > S_n$	x			
						$\left.\begin{array}{l}\varphi_{en} > S_M \\ \text{and} \\ \varphi_{sn} > S_M\end{array}\right\}$			x	

/ Second part fig. 2 /

Circuit	Parameter	Address	No. of param.	No. of chains	Scanning cyc.takes	Law of interven.	Actions			
							Alarm	PR	SC	Special Actions
Feeding zone heavy water	Temperature (T) Flow (F)	Outlet supply channel	2 x 16	2 x 16	1s	$1/16T > S^{T}_{1}$ ou $1/16F < S^{F}_{1}$	x			
						$2/16T > S^{T}_{2}$ ou $2/16F < S^{F}_{2}$ ou $\left\{ \begin{array}{l} T_n > S^{T}_{2} \\ \text{and } F_n < S^{F}_{2} \end{array} \right.$		x		
						$2/16T > S^{T}_{3}$ ou $2/16F < S^{F}_{3}$ ou $\left\{ \begin{array}{l} T_n > S^{T}_{3} \\ \text{and } F_n < S^{F}_{3} \end{array} \right.$			x	
	Pressure (P)	Expansion vessel	1	3	1s	$1/3\ P < S_M$				Automatic circuits D_2O (depressurization shut-down)
						$1/3\ P > S_1$	x			
						$2/3\ P < S_2$			x	
	Level	Expansion vessel	1	1	1s	$L > S_M$				Automatic circuits D_2O (supply shut-down)
						$L < S_1$	x			Automatic circuits D_2O (emergency supply)
						$L < S_2$				Automatic circuits D_2O
						$L < S_2$ and 1/16 $F < S^{F}_{3}$			x	Automatic circuits D_2O (shut-down of principal pumps) Start-up of auxiliary pumps) and expansion vessel depres-surisation

SYMBOLS USED (fig.2)

PR = Power reduction

SC = Scram

S = Reference level (S_1 = first level, S_2 = second level ...)

S^F = Flow reference rate depending on the number of pumps in operation. It is automatically modified by the computer which receives an "all or nothing" signal for each pump.

P = Average value of neutron power

k = coefficient taking into account loop characteristics

The index n (e.g. T_n) indicates the number of the element on which the measurement is made.

The fractions appearing in the intervention law indicate the proportion of measurement taken into account.

SECTION 8

SAFETY PROCEDURES

Index

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1. Foreword

The ESSOR plant is subject to the italian law and in particular to the provisions of the nuclear act(D.P.R. n° 185) of the Italian Republic. The nuclear act delegates in many subjects the responsability to the nuclear plant manager, assisted by the safety comittee (Collegio dei Delegati) working in close contact with the nuclear authority (CNEN) and submitted to its technical inspection. The safety problems involved by the experiments conducted in the ESSOR plant are discussed only between the customer and the plant manager. The latter justifies and supports the experiments to the italian authority (CNEN e Commissione tecnica ROMA) when their incidence on the plant safety goes beyond the limits established in the "Technical prescriptions".

In short, the safety problems of the ESSOR reactor and related experiments are under strict control, and every test requires a detailed description, but the procedure does not involve any administrative burden for the customer, which has only to contact the plant manager and supply every useful technical information.

2. Generalities

The safety problems resulting from the experiments carried out in the ESSOR plant are usually handled in three subsequent steps :

1. The safety secretariat of the plant examines the problems involved by the carring out of the experiment, in close contact with the applicant of the experiment and with the department of the research center (health physics, medical service, protection service, etc...), hearing on some particular aspects of the problem, the opinion of the italian authorities(CNEN, ANCC, ENPI, etc...).

2. The problem is the examined in the Safety Committee of the plant (Collegio dei Delegati), an organ imposed by the italian nuclear law, in which are sitting engineers and technicians of the main technical departments of the plant.

3. The experiment is finally submitted to the italian authority (CNEN) which, after hearing a technical committee, grants the operating authorisation and issues the technical prescriptions, i.e. the limitations concerning the equipment and the carring out of the experiment.

At the same time, every single part of the plant, and the whole undergo the legal inspection and test procedures, under the control of technical supervisors (from CNEN, ANCC, ENPI, etc...)

3. <u>Documents requested for the authorization</u>

The safety documents requested for the authorization are in particular a detailed description of the plant, the safety considerations, the analysis of normal operation hazards, the maximum credible accident, and the operation manual for normal operation and accident conditions.

4. <u>Procedures for new installations</u>

To settle the performances and main technical datas of a new installation, the applicant of the experiment must work in close contact with the safety secretariat. Their cooperation goes through the following steps :

1. Examination of the preliminary project, made by the applicant,

2. Joint examination of the preliminary project by the applicant and safety secretariat.

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3. Beginning of the safety study (dynamics, stability problems, conventional safety of circuits, shielding calculation etc...) and of experiments in order to confirm the theoretical assumptions.

4. Detailed project study by the applicant.

5. Joint examination of the final project by the applicant and safety secretariat.

6. Verification of safety calculations.

7. Construction, under the responsability of the applicant.

8. Inspection during the construction, including single and general tests, some of which attended by public inspectors.

9. Irradiation in core under the responsability of the plant management in the matter of plant operation, and by care of the applicant for the experimental parameters (subject to the limitations of the Technical Prescriptions).

5. Safety rules

The conventional safety provisions for the Ispra Research Center, and ESSOR plant are applicable to any single experiment as well during construction as during operation. The Research Center and the ESSOR plant bring the necessary technical support (medical examination, laboratory tests, film badges, fire fighting squad, decontamination team.)

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SECTION 9

AN IRRADIATION DEVICE : MK 5

1. MK 5 : Generalities

2. Thermohydraulic loop datas
   - loop
   - in-pile sections

3. Organic coolants : generalities

4. Some properties of organic fluids
   - composition W %
   - physical characteristics
   - purity experimentally obtained in loop
   - heat transfer

5. Loop coolant conditioning features

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SECTION 9

AN IRRADIATION DEVICE : MK 5

1. MK 5 : Generalities

MK 5, "multiple loop" located in cave n° 5, is a closed-loop cooling system consisting of one primary circuit filled with either OMD or OM 2 (specifications of these fluids below) conveying the heat production of several in-pile sections to a secondary circuit through an heat-exchanger.

The secondary circuit is also a closed-loop system filled with Thermip and transferring the calories to an external air-cooled radiator (specifications of the Thermip below).

This plant has a power extraction capability of about 1.8 MW per channel. The primary circuit, designed for 360° C nominal, 420° C maximum operating temperature, may be connected, through an already installed set of headers and feeders, to a number of channels (up to 8).

Neutronic, thermodynamic and safety considerations make it desirable to retain the 4 or 5 channel options.

With the 5 channels hypothesis , it should be possible to force in each channel a flow of 100 m^3/h max. of organic coolant with an inlet pressure of 15 kg/cm^2 and a temperature range between 300 and 360° C. In that case, the power extraction capability per channel should be about 2 MW.

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This makes it possible to irradiate in each channel an experimental fuel bundle of natural to slightly enriched uranium with high power ratings (in the range of 10 KW/cm), or to cool such irradiation devices as rigs or capsules located in one or two organic channels, the remaining channels containing fuel elements (experimental or boosters) for reactivity balance.

In any case : each channel must contain either a fuel element, or an irradiation rig or a replacement container. No channel can be left void due to safety considerations.

2. <u>Termohydraulic loop datas</u>

/Loop/

- primary coolant...............eutectic OMD liquid at room temperature
- max. flow.....................620 m^3/h
- In-pile section pressure
  loss..........................7 to 8 kg/cm^2
- temperature range.............150° C to 350° C
- power extraction capability...10 to 15 MW depending on temperature
- max. pressure.................40 kg/cm^2 pumps outlet

/In-pile sections/

- channels with SAP or Zr-Nb 2,5 pressure tubes, Ø int. 92 mm
- max. pressure.................15 to 20 kg/cm^2 depending on temperature
- max. flow.....................100 m^3/h
- temperature range.............150° C to 350° C.

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3. Organic coolants : generalities

The fluids consisting of mixtures of polyphenyls are not just exotic and related to a single reactor concept, as it has been seldom claimed.

These fluids have already found a large application in the field of industrial and domestic heat transport.

Their thermal performances are under some aspects comparable to water, with less power extraction capatibility, but with the great advantage of a low vapour pressure, a very low corrosion rate of the usual systems materials and a fairly low rate of chemical reactions with uranium, sodium, etc...

Sheath to coolant heat flux can reach 180 W/cm^2 in the mean loop temperature and pressure conditions without nucleate boiling. Burn out heat flux is at least 260 W/cm^2 in the same conditions.

On the negative side, the polyphenyls mixtures do have, when not properly purified, a known tendancy to foul the heat transfer areas. The existing loop coolant conditioning features are described in p.5 page 9/9.

Fire and explosion hazards do exist, but they are minimized when operating below 360° C, and may be easily kept under control by means of appropriate devices and precautions, as is the case of MK 5 plant.

The main primary fluids are considered :

- OM 2 which is especially interesting for heavy in-pile applications, but which is solid at room temperature (with inherent complexity of start-up procedure and plant preheating)

- OMD which is an eutectic compound, remaining in a liquid state at room temperature ; the "in-pile" performances of OMD are lower than those of OM 2 but similar to those of the well-known HB 40 used by the Canadian AECL in their WR-1 reactor.

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The secondary fluid, Thermip or ESSO 200 fluid (chemically quite close to methylnaphtalene) are also good heat transfer mediums, liquid at room temperature, very similar to light-oil and a solvent of OM 2 and OMD. For that reason, Thermip and ESSO 200 are used as a general purpose fluid in several subsystems of ESSOR.

/ Conclusion /

By means of appropriate analogies and a proper adjustment of the operating conditions of the loop, it is possible to use these organic coolants in substitution to water for irradiation experiments of capsules , rigs and fuel elements.

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4. Some properties of organic fluids

	OM 2	OMD	Thermip P2	ESSO 200
Composition W %				
- Biphenyl	< 1	25-27	-	-
- O-Terphenyl	15-25	53-55	-	-
- m-Terphenyl	70-80	17-19	-	-
- p-Terphenyl	< 5	< 1	-	-
- 1 and 2 methyl-naphtalene	-	-	95	38
- naphtalene	-	-	4	7
- alkylnaphtalene	-	-	< 1	29
- phenanthrene	< 1	3	-	-
- others organic components			< 1	(C 10-16) 13 (> C 16) 13

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	OM 2	OMD	Thermip P2	ESSO 200
Physical characteristics				
- initial melting point ° C	60-65		- 15	- 30
- liquidus point ° C	$<$ 90	$<$ 20	- 5	- 18
- boiling point ° C	355	295	230-255	230-280
- flash point ° C	$>$ 150	$>$ 130	$>$ 100	$>$ 100
- autoignition temp.° C	$>$ 500	$>$ 500	485	$>$ 485
- density (gr/cm^3)	120°C 1.02 300°C 0.88	25°C 1.07 300°C 0.85	25°C 0.99 200°C 0.84	25°C 0.99 200°C 0.87
- dynamic viscosity (centipoises)	120°C 2.1 300°C 0.41	25°C 50 300°C 0.31	25°C $\sim$ 3 200°C $\sim$ 0.3	25°C $\sim$ 4 200°C $\sim$ 0.4
- specific heat (cal/g ° C)	120°C 0.45 300°C 0.5	25°C 0.39 300°C 0.70	25°C $\sim$ 0.39 200°C $\sim$ 0.52	25°C $\sim$ 0.4 200°C $\sim$ 0.6
- thermal conductivity (10^5 cal/cm sec °C)	120°C 31.5 300°C 27.0	25°C 33.9 300°C 26.8	25°C $\sim$ 32 200°C $\sim$ 25	25°C $\sim$ 33 200°C $\sim$ 26
- vapor pressure (bar)	420°C $\sim$ 3	420°C $\sim$ 8	350°C $\sim$ 7	350°C $\sim$ 7

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	OM 2	OMD	Thermip P2	ESSO 200
Purity experimentally obtained in loop				
- Cl ppm	< 0.22	< 0.2	< 5	< 5
- S ppm	< 30	< 30	< 30	< 30
- H_2O ppm	∼ 100	∼ 100	< 200	< 200
- bound organic O ppm	∼ 250	∼ 250	-	-
- ash ppm	< 5	< 5	< 5	< 5

Heat transfer

For all these fluids ,within ± 5 % accuracy :

$$Nu = 8.35 \times 10^{-3} \; Re^{0,9} \; Pr^{0,4}$$

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5. Loop coolant conditioning features

In order to maintain correct conditions of the coolant, the MK 5 loop is connected to a purification section which consists in :

- one heat-recuperator and one electrical heater to keep constant temperature in this section with any inlet temperature of the main circuit, max flow 3 m^3/h, max temp. 350° C

- a filter battery, max flow 3 m^3/h, 5 microns (compressed silica wool beds)

- a chlorine adsorber, max flow 1 m^3/h (palladium deposited on alumina pellets bed)

- two adsorbers loaded with Attapulgus clay and silica-wool back-filters. A correct flow of coolant passes through these columns in order to adsorb the oxygenated high molecular weight organic polymers which are mainly responsible of the fouling.

- A degaser, max flow 3 m^3/h, under partial vacuum (400 torr). Eliminates dissolved gases (N_2, H_2O) and coolant decomposition light produits (H_2, CH_4, C_6H_6 and other organic compounds with a boiling point lower than 200° C)

- a distillation column, max flow 250 l/h under partial vacuum (200 torr) Separates the High Boiler Residues(M.w. higher than 250) formed by radiolysis and pyrolysis of the coolant, which would cause changes of physical properties (viscosity) and increase of fouling potential.

- a water injection system in order to compensate the losses of water during the degassing process. In fact, the zirconium alloy hydruration rate is minimum for a water concentration in the coolant of 100 $\pm$ 25 ppm

- two pressurization pumps feeding the clean coolant to the main circuit through the heat recuperator. The flow of these two pumps is regulated in order to keep a constant level in the main circuit expansion tank.

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/ ENCLOSURE OF SECTION 9 /

PHYSICAL PROPERTIES OF ORANIC COOLANTS : COMPATIBILITY

Material	Organic fluid	Source	Behaviour: Testing temp.	Behaviour: testing time	Behaviour: results	Remarks
STEEL						
304	Santowax	(2) (3)	360	up to 2000 hours	satisfactory	Normally stainless steel behave well in organic with little chlorine
	Santowax + 500 ppm Cl_2	(2) (3)	360	after 2000 hours	strong corrosion	50 ppm chlorine produce deep and fast intercrystalline corrosion, especially in the transition zone of weldings. It is recommended to avoid stagnation of part of the fluid
monel	Santowax	(5)	400	30 days	$-\Delta p=6 mg/dm^2$	
REFRACTORY METALS						
Nb	OM_2	(7)	400	432 hours	$+\Delta p=12,9 mg/dm^2$ $+\Delta H=2 mg/dm^2$	Nb idritates very easily. Mo and W are the most suitable for utilization with organic fluids.
Ta	OM_2	(7)	400	432 hours	$+\Delta p=27,4 mg/dm^2$ $+\Delta H=0,5 mg/dm^2$	
Mo	OM_2	(7)	400	432 hours	$+\Delta p=0 mg/dm^2$ $+\Delta H=4,7\cdot 10^{-2} mg/dm^2$	
W	OM_2	(7)	400	432 hours		

Material	Organic fluid	Source	Behaviour			Remarks
			Testing temp.	Testing time	Results	
ZIRCONIUM ALLOYS						
Zr_2	OM_2 (H_2O=10 ppm)	(9)	400	1000 hours 5000 hours	$+\Delta$ H=1,0mg/dm^2 Δ H=3,5mg/dm^2	Zirconium alloys are easily subject to idridation, but the nuisance can be largely avoided by preliminary oxidation
Zr-Nb 2,5	Santowax	(2) (4)	400	360 days	$+\Delta p$=0,29 mg dm^{-2} day^{-1} Vc=6,2.10^{-3}mg/ cm^{-2} h^{-1}	
Ozhennite	Santowax	(2) (4)	400	310 days	$+\Delta p$=0,1 mg. dm^{-2} day^{-1} Vc=2,7.10^{-3} mg cm^{-2} h^{-1}	
Zr-Cu-Fe	Santowax	(2) (4)	400	220 days	$+\Delta p$=0,2 mg dm^{-2} day^{-1} Vc=4.10^{-3} mg cm^{-2} h^{-1}	

Material	Organic fluid	Source	Behaviour			Remarks
			Testing temp.	Testing time	Results	
<u>ALUMINIUM AND ALLOYS</u>						
AP_5	OM_2	(1)	400	up to 10^4 hours	excellent	
	OM_2+300 ppm Fe +100ppm Cl_2 + 500 ppm H_2O	(1)	430		loss of 10μ thickness etch 50μ deep	Aluminium and its alloys behave well in presence of organic fluid
Al-Mg (2,9%)	OM_2	(1)	400	up to 10^3 hours	$+\Delta p$=260 mg/dm²	
Anticorodal (Al-Mg-Si)	OM_2	(1)	400	10^4 hours	$+\Delta p$=80 mg/dm²	
Al-Si (0,8 %)	OM_2	(1)	400	12.000 hours	$+\Delta p<5$ mg/dm²	
Al-Si (9 %)	OM_2	(1)	400	12.000 hours	$+\Delta p<5$ mg/dm²	
AL-Cu (4,9%)	OM_2	(1)	400	8.500 hours	$+\Delta p$=3-4 mg/dm²	
Al-Nb	OM_2	(1)	400	12.000 hours	$+\Delta p$=4 mg/dm²	
Al-y	OM_2	(1)	400	up to 6.000 hours	excellent	
Al-Sb	OM_2	(1)	400	" "	excellent	
Al-Ce	OM_2	(1)	400	" "	excellent	

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Material	Organic fluid	Source	Behaviour			Remarks
			Testing temp.	Testing time	Results	
Al-Ca	OM_2	(1)	400	up to 6000 hours	excellent	
SAP 10 %	OM_2	(1)	400	up to 10^4 hours	excellent	
	OM_2 + 300ppmFe + 100ppmCl_2 + 500ppmH_2O	(1)	400	115 hours	etch 350 µ deep	
SAP 7%-10%	Santowax	(2) (3)	400		excellent	
URANIUM	Santowax	(5)	400	30 days	$-\Delta p = \sim 150$ mg/dm^2	Black surface
PHOSPHOR BRONZE	Santowax	(5)	400	30 days	$-\Delta p = 38$ mg/dm^2 black spots	
BERILLIUM	Santowax	(5)	400	30 days	$-\Delta p = 3$ mg/dm^2 blue	
UC pellet	Santowax	(5)	400	30 days	$+\Delta p = 1197$ mg/dm^2-white power	
UC_2 pellet	Santowax	(5)	400	30 days	$+\Delta p = 970$ mg/dm^2	seemingly no etch, but probably terphenyl absorption
SODIUM	Hydrocarbon	(6) (8)	< cracking temp.	-	excellent	no reactions

/ LITERATURE /

1) Comportamento alla corrosione dell'alluminio e su leghe in liquido organico a 400° C ....F.COEN
G.PIATTI
H.W.SCHLEICHER

AIM-XIII Congresso Milano 17-20 giugno 68

2) Some aspeets of materials in organic cooled reactors.....J. BOULTON
A.E.C.L.-2640, May 1966

3) Corrosion of structural materials in impure Santowax..R.S.NEYWORK
Report NAA-SR-7755-1963

4) The behaviour of zirconiumalloys in Santowax OM organic coolant at high temperatures.....................A.SAVVOTZKY
Report A.E.CL.-2118. 1964

5) The compatibility of some metals with Santowax...........H.E. DAVIES
AERE M/M.153 March 1957

6) Liquid metals handbook.....................................CAREY B.JACKSON
pag.12 ed. A.E.C. June 1955

7) Rapporto EUR 379 e. (1963)...............................H.W. SCHLEICHER

8) Analysis of the use of organic moderator in liquid sodium-cooled power reactor.............................WETCH J.R.
NAA-SR-280
see also TID 7007 Part. 1

9) Stability and compatibility of hydrogen barriers applied to zirconium alloys...F.BROSSA
F.COEN
H.W.SCHLEICHER
G.VOLTA

EUR 4098 e. 1969

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